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Captain W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S., President, in the Chair.

John James Aubertin, 33 Duke Street, St. James's, S.W.;
Charles Josephus Green, M.R.C.S., L.S.A., 10 St. Paul's Square, Preston, Lancashire;
Frederic Hammond, F.R.I.B.A., 2 Mercer's Road, Tufnell Park, N.;
William Harnett, Cullentra, Wimbledon Park, S.W.;
Rev. Thomas Roseby, M.A., LL.D., The Parsonage, Marrickville, Sydney, N.S. Wales, Australia;
Rev. Peter Hately Waddell, M.A., B.D, The Manse, Whitekirk, Prestonkirk, East Lothian, Scotland; and
Robert Wigglesworth, Esq., York, and 8 Victoria Street, S.W.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:

George Denton Hirst, Sydney, New South Wales, Australia (proposed by H. C. Russell);
Samuel V. Hoffman, 1 Chelsea Square, New York City (proposed by Chas. Lane Poor);
Henry T. C. Knox, F.R.G.S., Lieutenant, late Royal Navy, 17 Upper Montagu Street, W. (proposed by G. F. Chambers);
E. F. J. Love, M.A. (Cantab.), Lecturer on Physics at the University, Melbourne, Victoria, Australia (proposed by R. L. J. Ellery); and
Rev. Daniel Higham Sparling, B.A., Biddulph Moor Rectory, Congleton (proposed by T. K. Mellor).

Seventy-four presents were announced as having been received since the last meeting, including amongst others :

Astronomische Gesellschaft, Catalog, vi. Zone +40° bis +50° (Bonn), presented by the Society ; J. E. Gore, The Worlds of Space, and J. R. Hind, Illustrated London Astronomy, presented by Mr. M. C. Sharp ; *Nautical Almanac* for 1898, and ditto, Part I., presented by the Lords Commissioners of the Admiralty; photograph of *Orion*, &c., made with a small camera, presented by Dr. Sheldon ; a series of eight untouched enlargements of portions of the Moon, from a negative by Lœwy and Puiseux, made and presented by Professor L. Weinek.

Preliminary Note on a Modified (Oblique) form of Cassegrain Telescope. By A. A. Common, LL.D., F.R.S.

Reflecting telescopes on the Cassegrain system, but with the convex mirror placed so as not to obstruct the light from the object, and with the mirrors tilted so as to throw the image to one side of the large mirror, appear to have been made in Germany many years ago.

I first learnt this from Dr. Hugo Schroeder in the course of a conversation about the possible forms of the reflecting telescope. This was, I think, before I began the present 5-foot telescope in 1886. He suggested that I should make it on this principle, and I made some experiments with small mirrors, but, as far as I remember, I did not get better definition than the Herschelian form would give. More than one eminent authority on the theoretical side assured me that good definition was not possible on this plan, and I did not then pursue the experiments further. In 1892 I found it so difficult to properly fix a spectroscope to the 5-foot, and to manipulate it from the stage, and the danger of getting up and down from a high stage in the dark becoming rather pronounced, I determined to seek some more convenient form of telescope.

As I had a 5-foot mirror with a hole in the centre, I could use the Cassegrain form, but before doing so I decided to try again the oblique form, as this allowed high altitudes with my form of mounting. From my previous trials, and from what I had heard from others of the possible definition, I was led only to expect perhaps enough for spectroscopic work.

The results of my experiments, however, have been, in my opinion, so thoroughly satisfactory, that I think it right to lay them before the Society.

Having nothing to go upon except the fact mentioned by Dr. Schroeder, that small telescopes on this plan had been made, and not being able to attack the problem from the theoretical side, I had to do so from the experimental or practical side. I began by trying the effect of a convex mirror on the obliquely

reflected rays from a 20-inch mirror of short focus length (so that the adverse conditions would be intensified), using an illuminated pinhole at the centre of curvature. Experiment showed that at certain angles the astigmatism of the image from the concave mirror could be almost entirely eliminated by the opposite astigmatism of the convex ; this was very evident when extreme angles of obliquity were used. This compensating principle, once established, gave great hopes of success.

A mounting was erected to carry a 6-inch or 12-inch concave speculum, with provision for using various convex mirrors, and experiments made to find the combination of curves and angles that would give the best definition on stars. Many experiments were made with more or less success, and a great deal of time was lost through bad weather. Combinations that gave excellent results on the Sun failed to give a perfectly round image of a star. With mirrors smaller than 6 inches a very fine stellar image was obtained on more than one occasion. This trial telescope was given up in favour of an artificial star in the workshop and a paralle' beam from a 6-inch achromatic ; this allowed the carrying on of the experiments continuously.

Hitherto the angle of reflection from the small mirror had been kept the same as that from the large one, but it was soon found that to get proper definition the angle of the second reflection had to be considerably larger than the first.

The conditions that seemed to answer best, and which gave, as far as could be seen with this arrangement, perfect definition, were, a focal length of the concave mirror of 10, aperture being 1, a radius of curvature for the convex mirror $\frac{3}{4}$ of concave, and distance from concave $\frac{2}{3}$ of focal length ; the angle between first central incident and reflected ray being 5° 30′, and between the second 12° 30′.

With these conditions it was decided to try this form of telescope on a large scale, using as much of the 5-foot mirror as the focal length would allow under these conditions (about 32 inches) ; the flat mounting of the 5-foot was cleared away, an 18-inch tube about 20 feet long was fitted to the main tube, with an eye-end and arrangement for carrying a convex mirror with adjustments. Two 15-inch convex mirrors were made to the proper curvature. With this arrangement the stars were not perfectly round—in fact they all had tails, and in appearance were very like comets with short tails. Definition was fairly good on the Moon, as photographs taken with this telescope which are laid before the Society show. They are almost, if not quite, as good as any I have hitherto obtained.

The defect in the image of a star was considered to be due to the fact that owing to the shape of the square tube of the 5 foot and the want of sufficient play to move the mirror, an eccentric portion had to be used. This difficulty could not be overcome, so it was decided to make a 30-inch mirror of the same focal length and fit it in the cell of the C speculum, which was in

the workshop. This mirror was made and silvered, and the C speculum taken out of its cell and this mirror put in, eccentrically as regarded the cell, but in the proper position as regarded the position of the convex mirror and the possible place of image. The B mirror was taken out of the telescope and the 30-inch mirror and cell put in its place. This was completed a few days before last Christmas, and the first opportunity taken of examining a star ; when it was found that, as far as could be seen on that night, which was not very good, the stars were round, and free from any kind of appendage. Inside and outside the focus the discs were quite circular. Observations since made show that with a power of 1100 the image of the star is not quite round, with lower powers it seems so. This slight defect, I consider, may be due to a slight want of adjustment.

On the Moon the definition was very fine indeed, finer than anything I have yet seen. *Jupiter* was very finely seen in a quite dark field. This was a striking contrast to the usual field with the 5-foot when such a bright object as *Jupiter* was under examination.

The advantages of this form of reflecting telescope are many and important, particularly so in the case of very large telescopes. The greatest gain is, perhaps, in the change of position of the image, so that a low stage near the centre of motion of the telescope and the ground level, will take the place of the high stage with its continuous shifting to suit the height of the end of the telescope and the motion in time.

The increase of focal length is a gain both for visual and spectroscopic work ; it may not be so good for nebular photography, but it is quite an open question whether the larger primary image is not at any time worth the greater time in exposure required, and plates are improving so rapidly that this will not be felt. (Using the 5-foot aperture some years ago, I gave quarter of a second exposure to the Moon. In November last I took a picture of the Moon with a convex mirror, giving an equivalent focal length of about 80 feet and an image $8\frac{1}{2}$ inches in diameter. Using only one foot aperture and two seconds exposure, I obtained a picture with ample density.)

The place of the image being near the strongest part of the tube, any kind of apparatus can be rigidly attached and manipulated under the most variable circumstances.

The dark field to which I have alluded is a great advantage on such objects as *Hyperion*, and the absence of the cause of the diffraction lines (the supports of the small mirror of the Newtonian) will tell on photographs of stars.

There is hardly a defect under which the large reflector at present labours that this plan of telescope will not remove, whilst it brings in some distinct gains of its own—as, for instance, the substitution of a convex for a plane mirror, and the great shortening of length of tube for a given focal length. In this latter respect the gain can be very great, an equivalent focal

length of, say, 200 feet, requiring in the case of the Newtonian a tube nearly this length, can be obtained by a tube of about 66 feet. In no other way could such a large primary image as a focal length of 200 feet would give be obtained, while retaining, say, 1° of the field. The image of the Moon would here be about 22 inches in diameter, with the above relation of curvature of surfaces, but this relation need not necessarily be adhered to, where, for the Sun or Moon, the aperture might be very much less than in the proportion given, as an increase in the curvature of the convex mirror produces a longer equivalent focal length ; and as this can be done more easily as the aperture of the concave mirror is reduced, and the first angle made smaller, a much greater equivalent focal length could be obtained ; and as I have shown, one foot of aperture is sufficient to give an image of the Moon when the equivalent focal length is 80 feet, a mirror of, say, 2 feet aperture and a slightly longer exposure, mounted on any of the very large refractors in existence, would easily give a much larger primary image—too large, perhaps, to photograph as a whole, but excellent for portions of such an object as the Moon.

The conditions I have given may not be the best to get the finest definition : probably they are not. It is easy to see that where there is a balancing process at work between the two mirrors, the angles of incidence and the place where the image is produced have an importance, as well as the curves of the mirrors. With a parabolic mirror and a spherical convex, the image is as it would be in the Cassegrain form, with these mirrors over-corrected. Whether it would be an advantage to reduce the amount of correction given to the concave mirror, to make it as if the focal length were to be the equivalent focal length ; or whether it would be better to obtain this correction, as in the Cassegrain, by making the convex curve an hyperboloid, is yet to be seen. I am working at this, and hope to have something from trial ; but, in view of the possibilities of this form of telescope, I hope that some competent person will take up the investigation of the theoretical conditions involved, so that the best can be made of this form of reflecting telescope.

Preliminary Note on the Determination of Terrestrial Longitudes by Photography. By Captain E. H. Hills, R.E.

The question of the practicability of some method for the determination of longitudes by means of photographs of the moon and stars is one that has engaged the attention of several experimenters.

It is one of great importance for the explorer and surveyor, the inaccuracy of the methods at present available being so great that they are practically never employed in the field.

Among others Dr. Schlichter, in England, and Dr. Runge, in Germany, have worked at this subject. The latter attempted no great degree of accuracy, but directed his attention rather to the question of the possibility of obtaining a rough approximation by the use of an ordinary photographic camera and watch, than to the investigation of the maximum accuracy obtainable by using a suitable instrument. At the same time Dr. Runge was, I believe, the first to suggest that it was not at all necessary that the Moon and star exposures should be made at the same time. This, as will be seen, is an integral part of the method now brought before the Society.

Dr. Schlichter worked on the method of photographing the Moon and a bright star near it, and measuring the lunar distance on the plate. There seems no doubt that results can be obtained by this method far exceeding in accuracy any that can be obtained by the use of a sextant or theodolite. The principal objection to its general use seems to lie in the fact, that there would be very few nights in the year when it could be employed, unless the photographic plate were made to include a large angle, which would be undesirable for many reasons. It is also an objection to this method that the measurement of the angular distance between Moon and star involves a knowledge of the focal length of the lens, and that change of temperature would affect the result in a degree by no means negligible.

The present method is available any night that the Moon is visible, and the reductions involve a knowledge only of the approximate position of the optical centre of the plate, which change of focal length will not affect. It is as follows :

The camera is set up so that the image of the Moon is about the centre of the plate and a series of instantaneous exposures are made, allowing such an interval between the exposures that the Moon images on the plate will not overlap, *i.e.* from $1\frac{1}{2}$ minutes to $2\frac{1}{2}$ minutes according to the Moon's age.

After a set of, say seven, Moon exposures the camera is left untouched until bright stars of approximately the same declination as the Moon have arrived at the same point in the heavens. The camera is then opened for periods of one minute and the stars allowed to impress their trails on the plate. These star exposures would be repeated four or five times. It is immaterial whether the star or the Moon exposures be made first, and if found convenient two sets of star exposures may be made in order to get stars on both sides of the Moons.

It is obvious that if the L.M.T. of the Moon and star exposures be known such a plate gives all the data necessary for computing the Moon's R.A. at the time of each exposure, and hence the G.M.T. and longitude.

The camera employed was one specially designed for this work. It was made regardless of weight, and is somewhat heavy (55 lbs. including stand). This weight might, if thought advisable, be considerably reduced in a future pattern.

The only two essentials are:

(1) Stability. A camera of this size, 19½ inches focal length, in combination with a suitable micrometer, may be looked upon as an instrument reading to seconds of arc, and will require the same degree of stability. There is, however, this in favour of the camera, that it need not be touched from the first exposure to the last one, and the observer may remain at a distance of several feet from it, the exposures being made by a pneumatic shutter actuated by an india-rubber ball and tube; and this shutter may be placed on a separate stand.

(2) Means of adjusting the plate at right angles to the optical axis.

This is the only instrumental adjustment required, and is done as follows:—The sensitive plate in the dark slide is pressed up against three sharp-pointed screws, which puncture the gelatine film, and leave three points from which the position of the plate in the slide can be determined. To adjust and find the "centre" of the plate the camera is placed lens downward over a mercury bath, and a piece of plate glass placed in the position of the sensitive plate and levelled. Then that point on the plate which coincides with its reflected image is the point at which a perpendicular from the centre of the lens cuts the plate. The position of this point with reference to the points of the three screws being once found, it can be marked on the sensitive plate after exposure and development.

The lens used with this camera was a Dallmeyer Rapid Rectilinear, of 19½ inches focal length.

The measurements were done with a micrometer reading to ·001 mm.

Two axes approximately at right angles, and approximately parallel and perpendicular to the meridian through the centre, were ruled on the plate with a needle, and the coordinates measured from these. The semidiameter of the Moon images was measured on the plate, so that coordinates of the Moon's centre were obtained.

The method employed for reducing the measurements is that worked out by Professor H. H. Turner for reducing the Astrographic Chart plates. (See *Monthly Notices, R.A.S.*, November 1893.) The R.A. and N.P.D. of the centre can be found by any approximate method; it will suffice if they are correct within a few minutes of arc.

No small part of the success of this as a practical, working method of longitude determination is due to these elegant and convenient formulæ, without the aid of which the computation of a plate would be most laborious.

The two plates, of which the results are given below, were exposed at the Royal Engineer Observatory, Chatham, on the

night of 1894 October 16. In these first experiments the camera was placed on a solid masonry pier. In each case seven Moon exposures were made, and *Jupiter* and *Aldebaran* were used as reference stars. The times were taken with the Observatory clock, transits being taken as opportunity offered.

Any error in time will produce the same error in the resulting longitude, but it is evident that any error in the assumed clock rate will, by affecting the scale of R.A. on the plate, produce a similar error in the Moon's R.A., and hence a large error in the longitude.

The following tables show the longitude as worked from these two plates :

	Plate 1. Longitude.		Plate 2. Longitude.	
	m	s	m	s
Moon 1	1	59·4	2	4·2
2	2	4·8	2	8·3
3	2	3·5	2	8·1
4	2	12·7	2	12·0
5	2	13·1	2	6·1
6	2	7·8	2	7·8
7	2	8·2	2	6·7
Mean	2	7·07	2	7·60

The true longitude was $2^m\,8^s\cdot13$, and the errors of these two determinations were, therefore, $1^s\cdot06$ and $0^s\cdot53$ respectively.

The principal source of error that this method is liable to, is the difference in refraction, owing to the different states of the atmosphere at the times of the Moon and star exposures. This error will disappear if the photograph be taken on or near the meridian, because in that case a change in apparent altitude will not affect the Moon's R.A. as measured from the plate. It is noteworthy that of the two plates, given above, No. 2 was exposed on the meridian, whereas in the case of No. 1 the Moon was some three hours from the meridian. It may be only an accidental coincidence that the result of No. 2 has only half the error of that of No. 1, but there is no doubt that the conditions for maximum accuracy are to expose near the meridian, unless there are stars in such a favourable position that only a short interval is necessary between the two sets of exposures.

It is, of course, essential that more plates should be exposed in order to gain further experience of the method, but it seems reasonable to suppose that this will result in increased accuracy being obtained, and even as the results stand now they are many times more accurate than could be obtained by any other method with a portable instrument.

Note.—The condition given above as regards exposure on the meridian being essential for obtaining the maximum accuracy is

only correct if the Moon's R.A. is used in finding the longitude, as was the case with the plates of which the results are given above. Professor Turner has pointed out that if the Moon's place be left in standard coordinates, and not converted into R.A., it is possible so to select the coordinate axes that the refraction error would be eliminated in all cases.

Notes on Suitable Stations in Norway for Viewing the Total Eclipse of the Sun on 1896 *August* 8. By Colonel A. Burton-Brown, R.A., F.G.S.

It having come to my knowledge that some doubts had arisen as to the suitability of Norway as a post of observation for the total eclipse of the Sun in 1896, and having had both experience in total eclipse expeditions and of travelling in Norway, I thought I could not do better than spend my summer holiday in obtaining information that might be useful to Fellows of this Society and astronomers generally. Accordingly, I determined to make a special tour of observation both to the west coast, and also to Finmarken, Lapland, and the Russian frontier on the east coast. It was clear to me that some notes that had been published on the subject entered somewhat into the region of speculation, and might possibly in such an exceptional country as Norway, broken up into mountains and fjords, and where it was difficult to get trustworthy maps or guides, result in disappointment. Having, therefore, arranged to spend some weeks on this work, I started early in June for Trondhjem and the North, and have now the pleasure of laying before the Society the result of my observations. Since my return, in order to compile a suitable map to illustrate this paper, I wished to verify certain astronomical work, and I desire to express my thanks to Professor Turner and to Mr. A. C. D Crommelin for useful notes and calculations, and in a very large measure to Captain Wesfel, of the Norwegian Artillery, who accompanied me in my journey through Finmarken, and whose knowledge of Lappish and Russian enabled me to penetrate far up the Tana River and other out-of-the-way parts amongst the Finns. My own knowledge of the languages, and of Laplanders' and Norwegian manners and customs, also stood me in good stead. I had previously found that on travelling out of the beaten track very little dependence can be placed on guide-books—even the usually reliable Baedeker is full of errors—and this made me more anxious that astronomers taking part in this expedition, especially as some of the posts would be found in isolated and more or less un-get-at-able spots and difficult of communication, should not be led astray in this matter. Statements having approximate truth may be good enough for ordinary tourists, but yet utterly insufficient for the careful work of an observer of an eclipse expedition.

It appeared to me that in selecting stations in such an exceptional country as Norway, many points must be considered that do not apply to most places; thus it is not enough to know that A is twenty miles from B without also knowing how many fjords lie between, how many peaks three or four thousand feet in height, how many glaciers, and how far they are crevassed, if the mountains are passable, and if so what weight besides himself a man can carry up. Those people who have visited Norway, and the more so those who have travelled in the interior and north of the country are surprised at the almost impossibility of moving at all except by the fjords and certain made roads. These generally may be said to extend as far north as Trondhjem, lat. 63°26′; long. 10° 30′ about. After that, on the north and north-east coast and Russian frontier, roads are the feeblest tracks generally, and the fjord communication only of a special character; the population, except at such places as Tromso, Hammerfest, Vardo, and Vadso, is very scanty, and chiefly confined to the sea coast, and in the latter case subject to considerable variation, according to the season of the year and the nature of the fishing. How far these points would affect an astronomical expedition will be seen later on. It became necessary to divide my tour of observations into two parts: first, the easy part, on the west coast, the less valuable from an astronomical point of view, but which should not be disregarded, and which we may call the pleasure trip; and second, the difficult but more valuable part, on the N.E. of Norway.

Leaving Trondhjem, we take a N.N.E. course, passing Torghatten, an island of about 800 feet in height, and shortly after pass the Island of Donnæso, at the bottom of the map‡ on the west side, where we should be on the border of the shadow during totality; steaming north to Tommen Öe, which will have about one minute totality, a careful search for stations is kept. Lüröe is too low, Oxtinden Promontory too much inland. We reach Hestmandöe,* well within the 85 sec. line, and the Island öf Tränen, near the 12th parallel, too far west, though the central line passes close by; but having a longitude of only 12° 5′, the Sun is rather low. Height of ground, 3710 feet. Röd Löven† also, somewhat further eastward, and Bolgen, a peaked island, close to the central line, but rather too far westward; passing Omnæs Öe and Meloe, crossing the central line, we next round the Promontory of Kunnen, two or three miles above the central line, a rather inaccessible position of some 2000 feet high. The lighthouse Island of Slöt is, however, in all respects a desirable position, and Kunnen has a telegraph station—a valuable adjunct. Proceeding E.N.E. we pass the Island of Fuglöe, 2300 feet high,

* To illustrate the inaccuracy of guide-books, one gives Hestmandöe, through which the Arctic Circle passes, as 66° 50′, another, 66° 20′; a question of importance to astronomers.

† Röd Löven marked Rodö on map. ‡ See Plate 2.

steep and rugged, and 1½ miles further north Fleina, about 400 to 1000 feet—a good position. On the right is the Island of Sandhorn, with the Sandhornet Mountain of 3300 feet - a rare position for our mountaineers, only about five or six miles above the central line, with a minute and a half totality, and the Sun an altitude of 7½° about, the longitude being six or seven minutes over 14°. This position gives an uninterrupted view all round. For non-climbers the Arnöe Islands on west, where there are fishing stations, would afford an almost equally good position. These places are in easy communication with Bödo, whose lat. is 67° 17′, and long. 14° 24′ about, and which is ten miles direct north of the central line, where there is a hill to the N.E. of the town. Here excellent accommodation can be had, and a telegraph station exists. Further north is the Island of Lande Gode, within the 85 sec. limit. The Islands of Lundo and Engelo are on the northerly limit of the shadow of totality, and therefore useless. It seems to me that if Bödo was occupied as headquarters, with a steam launch at the disposal of the party, and Sandhornet, Arnöe, Fleina, Kunnen, or the lighthouse rock of Slöt, Bolgen, Röd Löven, or Hestmando as detached stations, a valuable area would be covered, although these positions have the astronomical disadvantage of the Sun's altitude being as low as 6⅚° to 7¾°, and the duration of totality but little over 1¼ to 1½ minutes. Yet, owing to the stillness of the atmosphere on the west coast of Norway at that time, and the general freedom from clouds on the horizon. some good results should be obtained. The further fact of the corona being seen through a considerable thickness of watery vapour would have both a spectroscopic and photographic interest *in comparison with similar observations taken at about double the altitude on the east coast.* The way to work this tour would be to take the ordinary Norse mail-boat from Newcastle to Trondhjem, *viâ* the Fjords, arriving at the end of July ; thence take the steamer to Bödo ; or if it is wished to extend the tour to the North Cape, a start of a week earlier must be made, and steamers changed at Hammerfest, or arrangements made to be disembarked at Bödo coming south ; or a steamer might be taken direct, slowly steaming over the central line and back. Although I have marked several islands in black on the map, my experience has shown some to be better adapted for many reasons than others. Thus Fuglöe is steep and rugged, and has no advantages over Fleina except height ; also Omnæs Öe is a troublesome place ; Kunnen is an almost inaccessible promontory of chert and granite rocks ; the Island of Slöt has a good anchorage for boats, and the Sun would not be masked by Kunnen during totality. Here also is a telegraph station.

Röd Löven and Omnæs have the disadvantage of being either east or south of those mentioned, and Bolgen, though well placed, would afford a steep and difficult climb. I have attached a map (see Plate 2) compiled from six or seven different English, French, Norwegian, Swedish, Russian, and other maps and charts,

reduced from the large scale one of $3\frac{1}{7}$ inch to a mile [shown at the meeting], and I have entered on it the most suitable stations both on the east and west side of Norway. The shadow is shown as extending from 12° to 32° longitude east of Greenwich, and the line of 1^m duration N. and S. of the central line (dotted) is also marked, the maximum totality on this central line increasing from 91^s to 104^s as we move eastward.

[The photographs handed round I must apologise for, as some are indifferent; but they will help, as will also the sketches, to illustrate and explain the paper.] I would now like to caution astronomers against guide-books, which are only suitable for casual travellers and those with ample time at their disposal; real information must be obtained from really good maps (difficult to get) and from people who have been on the spot and know what is required. Even that excellent guide "Baedeker" is more or less a fairy tale, and such astronomers who believe good accommodation is to be got at out-of-the-way places because a guide-book says so, may be sorely disappointed, as I have had the inconvenience of learning practically. Further, heights and distances from those sources must be received only as approximate. The writers of an interesting little paper suggest a station on the top of Sulitelma (see map and photo). As this would involve a special steamer up the Fjord from Bödo (or a still more difficult journey over lands and rivers), some eighty miles distant, several changes of conveyance, and four changes of boats to get to the bottom of the peak, then three or four days over glaciers and snow, on which journey all provisions would have to be carried, and even fuel and tents, part of the way, I cannot agree in thinking it neither dangerous nor very fatiguing, and I speak from mountaineering experience over 17000 feet high in the northern Himalayas. Norway is not open to tourists as Switzerland is, and before such an expedition is undertaken a course of mountaineering and arctic work should be undergone. Furthermore, no instruments of any size could be carried, and when once the peak is reached, the chances are ninety-nine out of a hundred that it would have its night-cap on, and no sun would be seen from it at all. This latter remark applies to all high mountains in Northern Norway, which have more or less snow on them, and are in the vicinity of glaciers. Thus the Bugönæsfjeld, for instance, near Vadso. If there is moderately high ground on islands such as I have mentioned, they are generally clear, but inland the reverse is the case. This year was quite an exceptional one, yet some of the photographs show clouds at or near the peaks. It may interest astronomers to hear that the "midnight sun" on July 9 in lat. 70° and long. about 18° 10′ was *perfectly* free from cloud. The temperature in its direct rays was 56° F., in the shade $52\frac{1}{2}$° F. (or only $3\frac{1}{2}$° F. diff.): its apparent altitude was about 5 diameters, and with a $2\frac{1}{2}$″ object glass it would not burn paper, and only charred it in the focus of a 4″ glass, and the lines of moisture in the spectroscope were strongly marked. But to pass on: leaving

the west-coast positions, we reach Tromso, and steaming up to Hammerfest signs of civilisation die fitfully away. The coast is bleak and barren. On reaching Hammerfest we see the spot where a late President of the Royal Society, General Sir Edward Sabine, R.A., carried on his Pendulum Observations in 1823, and where a conference of astronomers of Norway, Sweden, and Russia on their labours from 1816 to 1852 fixed the northern termination of the 25° 21′ meridian from the Arctic Ocean to the River Danube. Here we probably change steamers and round the North Cape, 71° 10′ 40″ N., and about 26° E. ; steering east we pass the Nordkin, and from there in a S.E. direction along a bleak, inhospitable shore of quartzite rocks to Vardo, on an island, this is about the N.E. corner of Norway, a good sized whaling station, and a fort, with some second-class hotel accommodation. The high ground here would do for an encampment, or at least that portion not occupied with fishing lines and dried or, still worse, drying fish. This place was used as an observing station in 1769 by the Austrian Hell for the transit of Venus ; and, being less than twelve miles directly north of the central line of shadow, might be advantageously occupied. It forms the most easterly station ; being in long. 31° 8′, and lat. about 70° 22′, it would have a duration of totality of over $1^m\ 31^s$, and the Sun's altitude of about $14\frac{1}{2}°$. It is easily get-at-able, no high ground obstructs the view, and provisions and labour are to be had. Passing south down a dreary coast of quartzite rocks and Silurian slates, we come to Kilberg, about ten miles south, and two miles inland. There is a hill about 500 feet high, but although this would be only five or six miles north of the central line, it is not in other respects a desirable station. Steaming S.S.W. we pass Store Ekkero, a promontory some twenty-five or thirty miles west of Vadso, which appears to have all the attributes of a good station, provided accommodation can be arranged for : the central line of totality passes over the southern point, and there is a free view to the S.S.E. and E.N.E., the Sun's azimuth at the local time of 18^h being 97° south towards east, and the duration of totality a maximum—viz over $1^m\ 41^s$, the Sun's altitude about $14\frac{1}{4}°$. Passing on to Vadso, the town of the Finmarken district, there are several hills, two or three hundred feet, easily accessible, and in all respects suitable for observing stations within three or four miles ; indeed, Vadso should be looked upon as the headquarters of an East Norway expedition. The local time of totality here would be $17^h\ 57^m\ 46^s$, and duration about $1^m\ 35^s$. All the aforementioned places are in telegraphic communication with most parts of Norway during the fishing season, and I have no doubt arrangements could be made for keeping the offices open as late as August 8. The temperature at Vadso is remarkably high, probably between 50° and 60° F. in August (I have known it in the early summer to be 90° F.), and from statistics and all I can learn locally, I think there is every chance of fine weather at that time. I have already paved the

way for an expedition here, and instructed a number of Norwegians in the neighbourhood.

Crossing the Varanger Fjord we come to Bugö, a Lapp fishing station, and within a mile and a half of the central line : the longitude is about 29° 50′, and latitude 69° 58′. Here the duration would be about $1^m\ 40^s$, with nothing to obstruct the view ; frequent communication could be had with Vadso at certain times of the day ; heliograph signals might be transmitted ; there are several sites hereabouts, but one in particular desirable. Baedeker's suggestion, however, that good quarters may be had anywhere hereabouts reads like a fairy tale, and is a pure fiction. But no doubt if arrangements were made beforehand, a structure might be obtained or a place run up. The Bugönæsfjeld I will leave to those who like to be in the clouds ! So little is known of it that every map shows it in a different position ; but if intrepid mountaineers are fond of carrying half-hundredweights up mountains, there is no reason why they should not have the satisfaction they desire, but they will find no one to do it for them.

In order to distribute the parties and multiply the chances of success, I would suggest some one party proceeding from Vadso to Seida, on the Tana River. This station is a good one for all points except the length of totality, which is only about $1^m\ 12^s$, and has the Sun at an altitude of about $13\frac{1}{2}°$. Polmăk, some 12 miles due south (reached by poling up the river), is not so easily got at, but astronomically better situated, and S.E. of it, about five miles, is a mountain over 1000 feet high ; but time did not enable me to explore it. About forty or fifty miles further up this river, in a S.W. direction, is Utsjoki, a place also that might be advantageously occupied in the Russian Lapland. The duration of totality here would be about $1^m\ 26^s$, and the Sun's altitude about 13° ; both at Polmăk and Utsjoki camp equipage would have to be taken. Both are in telegraphic communication with Vadso and Vagge, the latter place being at the mouth of the Tana Fjord. Karasjok is astronomically a good place, within four miles of central line, the Sun's altitude being about $12\frac{1}{4}°$ and duration of totality over $1\frac{1}{2}^m$. Much, of course, will depend on the number of observers it is proposed to send out, their powers of endurance, and knowledge of Lappish, Russian, and Norwegian for the east coast expeditions (except at Vardo).

If ladies purpose joining, I would recommend them to go to Bödo, on the west side, or Vardo, or possibly Vadso, on the east coast, on account of the accommodation at the first and third places. I think it might be possible to arrange with the mail steamboat companies to live and feed on board ship (which in this case would be changed every third day) during their entire stay at Bödo or Vadso. I have already been in negotiation with the steamboat companies on this subject. In any case, the lines of communication would be carried out best

by the Norway company's steamers for an eastern expedition, and probably for a western also. (It is quite unnecessary to consult Cook or Gaze on the subject, which would mean an extra cost of 10 or 15 per cent., and it can be done well without.) The Norse steam companies would doubtless also provide a steam launch, and fuel, to keep up communication between the various parties. With proper care and organisation, I think we have every reason to expect that success should crown our efforts; the weather in all the parts I have referred to is likely to be favourable, and the hardships not to be too great for those energetic women who help us everywhere to success. Yet they must be self-reliant in these out-of-the-way districts, and be ready to put up with inconveniences, mosquitoes amongst other pests being plentiful, and rendering one's couch not always a bed of roses.

This eclipse is also visible in Japan, on the Island of Yeso, the duration of totality being longer, and the Sun's altitude greater considerably; and observations on this station I shall be happy to refer to at a later period.

Total Eclipse of the Sun, 1896 *August* 8.

Table of Advantages of Suggested Stations.

Names.	Lat.	Long.	Totality.	Distance C. Line	Altitude of Sun.	Lodging accom.-modation.	Feeding.	Height. Suitable positions.	Description.	Telegraph Station.	Weather.	Communication.	Remarks.
	° ′	°	m s.	Miles.	° ′			Feet.					
Tommen Öe	66 15	12 50	1 10	S. 28	...	Nil	...	...	Island	...	Fair	Difficult, S.	See note (*a*)
Trænen	66 30	12 05	1 31	S. 2	6 21	Nil	...	2000	Island	...	Good	,,	
Oxtinden	66 26	13 11	1 16	S. 24	...	Nil	...	...	Promontory	Yes	Fair	Good, S.	Grono, a steamboat station
Hestmand Öe	66 31	12 50	1 25	S. 11	6 40	Fishing	Take some	1700	Island	Near	Good	Fair, S.	
Næsöe	66 35	12 40	1 23	S. 6		Unknown	...	...	Island	...	Good	Good, S.	
Röd Löven	66 42	13 08	1 28	S. 6		Fishing	Arrange	1200	Island	Near	Good	Good, Grono	See note (*b*).
Bolgen	66 48	13 13	1 29	S. 2	to	Nil	Arrange	700	Island	...	Good	Good, Grono	
Melöe	66 49½	13 28	1 27	S. 4		{ at Grono (near) }	Take some	2000	Island	...	Good	Good, Grono	
Kunnen	66 56½	13 33	1 28	N. 3		Yes	Take some	2000	Promontory	Yes	Good	Good, Bödo	
Slöt Öe	66 57½	13 31½	1 27	N. 4	7 16	Lighthouse	Take some	125	Lighthouse Ö	Yes	Good	Fair, Bödo	
Fuglöe	67 03½	13 50	1 24	N. 7	...	Fishing	Arrange	1200	Island	Near	V. Fair	Good, Bödo	
Flcina	67 06	13 55	1 22	N. 10	...	Fishing	Take some	400	Island	Near	Good	Good, Bödo	
Sandhornet	67 06	14 06	1 23	N. 5	...	Yes	Take some	3300–4000	Island	Yes	Good	Easy, Bödo	
Bödo	67 17	14 24	1 21	N. 10	7 45	Very Good	Good	50–400	Neck of land	Yes	V. Fair	Station	

Names.	Lat.	Long.	Totality.	Distance C. Line.	Altitude of Sun.	Lodging accommodation.	Feeding.	Height. Suitable positions.	Description.	Telegraph Station.	Weather.	Communication.	Remarks.
	° ′	° ′	m s	Miles.	° ′			Feet.					
Lande Gode	67 23	14 20	1 27	N. 17	7 44	Unknown	Arrange	500	Island	No	Good	Fair	Beieren Hill, 4000 feet, near Bödo
Vardo	70 21½	31 08½	1 31	N. 10	14 40	Fair	Good	50–150	Island	Yes	Good	Good	
Kilberg	70 16	31 06	1 35	N. 6	14 35	Indifferent	Arrange	350	Promontory	Yes, near	Good	Good	Sandstone rocks
StoreEkkero	70 05	30 10	1 41	N. 1	14 12	Fair	Arrange	50	Mainland & promontory	Yes, near	Good	By road, Vadso	
Vadso	70 04	29 47	1 35	N. 5	13 41	Good	Good	250–450	Mainland	Yes	Good	Good	
Bugönæs	69 58	29 50	1 40	S. 1½	13 40	Tents	Arrange	50	Promontory	Heliograph	Good	Good f. Vadso	Lapp & Finn
Seida	70 15	28 10	1 12	N. 23–27	13 25	Fair	Arrange	200–300	Inland, Hill	On Tana River: Yes	V. Good	Good	Mosquito tents required; mountain 1000 ft., near Seida; 3 sec. longer totality
Polmäk	70 02	28 05	1 21	N. 16	13 23	Fair	Arrange	100–1000	Inland, Hill	On Tana River: Yes	V. Good	Fair	
Utsjoki	69 45	26 48	1 27	N. 13	13 00	Tents	...	150	Inland	On Tana River: ...	Good	Difficult	
Karasjok	69 15	24 40	1 31	S. 4	12 20	Unknown	...	200	Inland	...	Fair	More difficult	

(*a*) S. means Salsovig, a steamboat station.

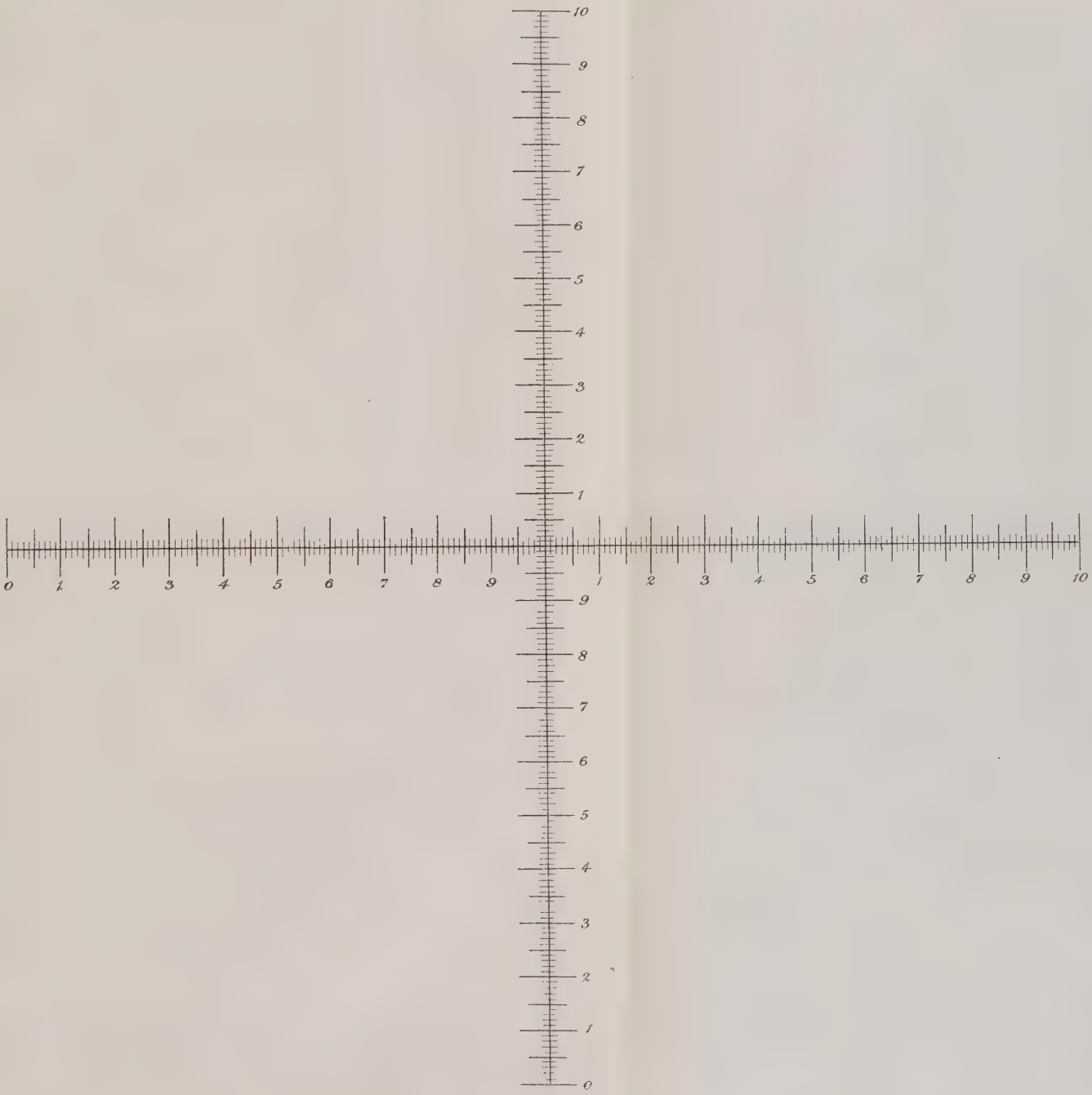
(*b*) In col. 8 "Arrange" means that feeding may be arranged for in part on the spot; "Good" means that Good feeding may be obtained there. Throughout the table the sign ... means "uncertain."

On the Measurement and Reduction of the Plates for the Astrographic Chart. By Professor H. H. Turner, M.A., B.Sc.

1. In a former paper (*Monthly Notices*, liv. p. 11) I briefly indicated a method of rectilinear coordinates, by which the reductions of measures on photographic plates could be made with comparatively little reference to spherical coordinates of any kind, especially the coordinates R.A. and Declination, and thus with very much greater simplicity and rapidity than by other methods. The method is specially applicable to the comparison of one photographic plate with another ; and in this case the introduction of R.A. and Decl. as a medium of comparison simply entails a very large amount of waste labour. For the comparison of a photographic plate with existing meridian or other observations, we naturally cannot escape dealing with R.A. and Decl. at some stage ; but it seems to me that, in view of the fact that the number of stars with which we shall deal photographically will probably enormously exceed the number to be dealt with in other ways, the transformation should be rather that of the comparatively few existing measures of R.A. and Decl. into rectangular coordinates, suitable for comparison with photographic measures, than of the numerous photographic measures into R.A. and Decl.

2. In a subsequent paper (*Monthly Notices*, liv. p. 489) I gave an example of such a transformation of R.A. and Decl. into suitable rectangular coordinates, whereby the measures of a number of plates of the *Pleiades* could be "reduced"—signifying by the term "reduction" the correction for errors of orientation, scale value, refraction, aberration, &c.—with very little labour. The Astronomer Royal and Mr. Dyson gave last month (*Monthly Notices*, lv. p. 60) an example of the facility with which four photographic plates could be compared *inter se*. I have also been privileged to see a paper which Captain Hills is communicating to the Society this month on the determination of longitudes by photographs of the Moon and stars, in which he expresses very kindly his indebtedness to the method of rectilinear coordinates for reducing photographs. Perhaps it is not too much to hope that, as its advantages become better known, the method of rectilinear coordinates for reducing, *and expressing the results of*, photographic measures will be generally adopted.

3. The object of the present paper is to give at greater length detailed directions for measuring and reducing the plates of the Astrographic Chart in accordance with the principles of this method. Much experimental work has been done both at the Royal Observatory, Greenwich, and the University Observatory, Oxford, the results of which it seems advisable to set down for the criticism, or the information, of others. It is quite probable that improvements may yet be suggested in various directions ;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for it takes some time to develop a new method, as we have found already ; and if some of the following statements appear a little arbitrary it is for the sake of brevity, and not from any desire to assume that the processes have taken final shape. I should wish here to record my indebtedness to the Astronomer Royal for the interest he has taken in the new method from the first, and for his valuable suggestions and criticism ; also to Mr. Dyson for similar suggestions.

4. *Measures.*—Theoretically the only requisite condition is that these should be *truly rectilinear*. Any micrometer which secures this is suitable. The only conditions which will further define the micrometer are practical considerations, and the form which experience has suggested as best suited to the special work of the Astrographic Chart is that alluded to in the paper by the Astronomer Royal and Mr. Dyson (*Monthly Notices*, lv. p. 60), in which the stars are referred to the lines of the *réseau* by means of a glass-scale in the eyepiece.* This secures

(1) Rapidity, the turning of a micrometer screw being avoided.

(2) An accuracy which is found to be *sufficient* while avoiding the use of too many decimal places, which would add seriously to the work.

(3) Convenience to the observer, it being no longer necessary to withdraw the eye from the microscope to read the screw—a tiring operation.

5. A diagram of the scale is given in Plate 3. The divisions on the scale represent each 0·01 of a *réseau* interval, or $3''.0$; and readings are made by estimation to tenths of these, or $0''.3$. In what follows measures are always expressed in *réseau* intervals. The readings are made thus : by the slow motions the star to be measured is brought centrally over the intersection of the scales ; and the readings of the scale are then observed where it is cut by the four sides of the *réseau* square in which the star-image lies.

6. A difficulty of some importance in the adoption of this form of micrometer is that of making the scales. Mr. Simms has been successful in some instances though not in others, and as yet the scale can scarcely be described as a commercial article. It is apparently a danger that in cutting divisions plain enough to be seen, and so close together as above-mentioned, the surface of the glass will break up. In trying to avoid this disintegration the divisions are sometimes cut so lightly as to be difficult to see in the microscope ; and the difficulty of seeing the divisions is tantalizingly greatest when the star images are just in good focus. The grain of the photographic film seems then to mix

* The authors have kindly credited me with the suggestion that a scale should be used instead of a micrometer screw; but the determination of the particular form is due to the Astronomer Royal and Mr. Simms.

itself up with the divisions and obscure them, although a turn of the focussing screw makes them distinct. We have, however, one excellent scale at Oxford, and there is another at Greenwich, so that the instrumental difficulties have been surmounted in special cases, and it only remains to make a certainty of surmounting them always. Meanwhile a very workable scale can be made by drawing carefully on a large sheet of card a magnified representation of it, and photographing this representation at the proper distance. A photographic scale of this kind has been used with satisfactory results at Oxford.

7. *Error of Runs.*—If all adjustments were perfect, the readings of the scale at the points where it cuts the *réseau* lines should be identical—*i.e.* the distance between two *réseau* lines should always be 1·000. Such perfection is not attainable in practice, and we have to consider

(*a*) How to make the difference between the readings as small (on the average) as possible.
(*b*) How to deal with residual differences.

To consider (*a*) first. The scale may be cut with the greatest care by the maker to suit the particular microscope, and yet different conditions of temperature, &c., may make a sensible "error of runs," so that the readings of the scale for the two *réseau* lines differ systematically over the plate by (say) ·003 (=0″·9). To obviate this there should be a screw adjustment *not only for the whole microscope with reference to the plate, but for the objective of the microscope with reference to the glass-scale.* Such adjustments are of course the business of the instrument maker. Mr. Simms has furnished them in the Greenwich and Oxford instruments, and if these are properly used before commencing measurement on a plate, the "error of runs," for any given *réseau* square, should never exceed ·003. That it may be so large in individual cases is due to errors such as

Errors of the *réseau* lines,
Distortion of the photographic film,
Curvature of the photographic plate,
Accidental errors of bisection, &c.

In the case of the curvature of the plate the remedy is comparatively simple: by means of the adjustments above mentioned we focus and adjust for runs afresh; or focussing afresh, we apply a correction for runs. In the other cases we must either undertake elaborate investigations or treat the errors as accidental. For reasons that cannot be here fully dealt with the remaining errors will be treated as accidental; and thus we have three sources of *accidental* error as against one which represents a *real* correction for runs.

I proceed to show how, so long as an accuracy of 0·001 (=0″·3) for the final reading is considered sufficient, the final reading may

be set down at once, without entering the readings at both *réseau* lines and computing a mean, corrected for runs.

We have remarked above that the difference between the two *réseau* readings should not exceed ·003—*i.e.* should be either ·000, ·001, ·002, or ·003. Suppose the difference to be ·002, *i.e.* let the readings be x and $x + ·001$. If the difference is *wholly accidental*, the adopted readings should be $x + ·001$. If the difference, however, is due to a *real error of runs*, then the adopted reading should be :

x	from $x = 1·000$ to $x = ·750$
$x + ·001$	,, $x = ·750$,, $x = ·250$
$x + ·002$	,, $x = ·250$,, $x = ·000$

the same reading ($x + ·001$) as in the case of accidental difference holding over the middle half of the scale, but being modified to agreement with the reading at the line *near the star*, when the star is within ·250 of either line. Finally, if we regard the error of runs as partly real and partly accidental, we should adopt the reading $x + ·001$ over a wider range, and restrict the adoption of x or $x + ·002$ to cases when the star is nearer still to the *réseau* lines.

Of the other values for runs likely to occur, that of ·000 needs no comment, and those of ·001 and ·003 will resemble that of ·002 with a slight complication as to raising figures. It need not be explained at greater length that a practical rule which will obviate any separate entry of the two readings, and consequent computation of, and correction for, runs, is :

Take the mean between the two readings (mentally), with an inclination towards the reading at the line nearer the star.

To those who are inclined to criticise this rule as rough and inaccurate, I would reply that no doubt a little accuracy is sacrificed, but a very large number of figures are saved thereby ; and, after all, it may be questioned how far the apparent loss of accuracy is real.

8. *Expression of the Results.*—The coordinates of a star may be expressed in various ways—in revolutions of a micrometer screw, in reputed seconds or minutes of arc, or in *decimals of a réseau interval*. It will be gathered from what precedes that it is proposed to adopt as the standard method of expression the *decimals of a réseau interval to three places*—that is, to estimated tenths of a division of the glass-scale. By making the correction for runs mentally the coordinates are set down at once in this form, say as 13·342 and 21·687. By thus taking a little care in the arrangement of apparatus, &c., ten figures suffice to reach and record a result over which fifty or sixty figures may easily be expended. The importance of this saving of figures in *every item* of such a large piece of work can scarcely be over-estimated. It remains, however, to adopt some convention for the integers. The *réseau* lines on many of the *réseaux* are numbered from

1 to 27, and they cannot be made always to agree with increasing R.A. and Decl. when photographs are taken both E. and W. of the pier. It will be better on the whole to neglect them and adopt a scale from 0 to 26, agreeing in one case with increasing R.A. and in the other with increasing Declination.

9. *Standard Coordinates.*—For an ideally-perfect set of measures on an ideally-perfect plate, oriented for 1900·0, it seems to me that the coordinates of stars expressed in this way might well be left as they are. The small number of stars on the plate whose R.A. and Decl. have been, or will be, measured in other ways can be compared with the measures on the plate with much less labour if their positions are converted into the above "standard coordinates" than if the photographic measures are all reduced to R.A. and Decl. for a given epoch; and further, any future photographs will be far more speedily compared with the plate without any reference to R.A. and Decl. at all.

Further, the fact that no plate is ideally perfect, either in the taking or the measuring, does not introduce any serious difficulty, for I have endeavoured to show that its defects, both accidental and systematic, can be simply expressed by linear formulæ. The coefficients of these formulæ are to be found from the known stars on the plates or from comparison with other plates, and while it will be convenient to make at once an approximate determination of them from the material at command, the final determination may be deferred. The work of finding the constants is not heavy, and may indeed be repeated several times without much waste of labour. The final determination should be based on the discussion of a number of overlapping plates—to fix the ideas, say a whole zone taken together—each plate being connected with its neighbour by two others, viz. one in the zone north and one in the zone south.

10. *Choice of Standard Coordinates.*—But if we stop here there will be an ambiguity. Every star occurs generally on two plates, and thus will have two pairs of standard coordinates in the sense of the last paragraph. Are both to be recognised? This would lead to some confusion. If a choice is to be made, what shall be the convention? The Astronomer Royal has proposed (and the proposition seems thoroughly satisfactory) that the coordinates in the *north* half of an ideal plate should stand, and those on the *south* half be converted into the corresponding coordinates of the overlapping plates whose centres are in the zone 1° south. This convention will be adopted for the present. It would seem advisable, however, at least in the final presentation of results, to subtract the number 13 from all the y coordinates, so that they may run from 0 to 13, and not from 13 to 26. In the southern hemisphere it should be the *south* half of each plate which is left untouched, if the same tables are to be available as in the northern hemisphere; the measures to be modified are, in fact, those in that half remote from the pole in each case.

11. *Transformation of Coordinates in the half of a Plate remote from the Pole.*—To save circumlocution, let us consider a plate in the north hemisphere; and let it be an *ideal* plate, *i.e.* let us first neglect refraction, aberration, errors of orientation, photography, and measurement; and let the coordinates of its centre be $20^h\ 8^m$, $+26°$. The S.W. quarter is overlapped by the N.E. quarter of the plate whose centre is at $20^h\ 4^m$, $+25°$; and the S.E. quarter is overlapped by the N.W. quarter of the plate whose centre is at $20^h\ 12^m$, $+25°$. It is required to transform the measured coordinates on the first plate so as to accord with those measured on these two overlapping plates. Let $(x_1\ y_1)$ be coordinates on the first plate, $(x_2\ y_2)$ on the second, and $(x_3\ y_3)$ on the third. The formulæ, as corrected by Mr. Dyson in *Monthly Notices* (liv. p. 573), will not immediately give us the relations between $(x_2\ y_2)$ and $(x_1\ y_1)$, because we are now measuring from the *corner* of the *réseau* instead of from the *centre*—but the transformation need not be given at length. The relations will be similar to the following, which, though not correct, were used in the work quoted in paragraphs 12 to 16, and will quite well serve the purpose of the present paper:

$$x_2 - x_1 = -\cdot00055x_1 + \cdot00759y_1 + 10\cdot688 + \cdot000025x_1y_1 + \cdot000023x_1^2$$
$$y_2 - y_1 = -\cdot00740x_1 - \cdot00056y_1 + 12\cdot138 + \cdot000023x_1y_1 + \cdot000025y_1^2$$

It will be seen that these expressions are not very difficult to calculate, and that the terms are small, excepting only the constant terms and the terms $+\cdot00759y_1$ in $x_2 - x_1$ and $-\cdot00740x_1$ in $y_2 - y_1$. Since x_1 and y_1 may be as large as $14'$, these latter may amount to one-tenth of a *réseau* interval, or 30 seconds of arc; and this limit is larger for plates of greater declination. But in view of the extensive nature of the work and the importance of saving labour, especially if it can be seriously reduced for every item, I have given some attention to methods of reducing the labour of applying these corrections within the smallest possible limits; and venture to hope that the result of the inquiry, as indicated in the next few paragraphs, will be found conducive to this end.

12. *Practical Method of applying the Corrections.*—It may not be out of place to give the successive steps by which the final method was arrived at. The first step consisted simply in dividing the corrections into two parts: expressions large enough to require logarithms or Crelle's Tables, and others manageable by mechanical or diagrammatic means. The former were simply the large terms above noted ($+\cdot00759y_1$ and $-\cdot00740x_1$) or the major parts of them; and as a first essay the parts $+\cdot007y_1$ and $-\cdot00\ x_1$ were selected for separate application, involving little arithmetic. This left

$$-\cdot00055x_1 + \cdot00059y_1 + \cdot000025x_1y_1 + \cdot000023x_1^2$$

and

$$-\cdot00040x_1 - \cdot00056y_1 + \cdot000023x_1y_1 + \cdot000025y_1^2$$

for application by mechanical means (omitting the constant terms 10·688 and 12·138). A series of curves was drawn corresponding to the values ±·0005, ±·0015, ±·0025, &c., of these expressions, by use of cross-ruled paper; and it was proposed to apply the uniform corrections ·000, ±·001, ±·002, &c., to stars falling in the spaces between these curves, as shown in fig. 1, Plate 4.

13. The next step was taken more or less accidentally. The curves were plotted by calculating the value of y_1 in the first case, and of x_1 in the second, for different values of x_1 and y_1 respectively. Taking the first case alone for brevity, we have

$$y_1 = \pm\cdot0005/(\cdot00059+\cdot000025x_1) + (\cdot00055x_1-\cdot000023x_1^2)/(\cdot00059+\cdot000025x_1)$$

and the calculations for $x_1=0$, 1, 2, 3, &c., were found to occupy more time than was convenient.

To reduce this labour it was proposed to apply separately, not the expression $+\cdot007y_1$ simply, but the expression $+\cdot00819y_1$, leaving for diagrammatic treatment

$$-\cdot00055x_1-\cdot00060y_1+\cdot000025x_1y_1+\cdot000023x_1^2$$

which can be put into the form

$$-\cdot000001\,(23x_1+25y_1)\,(24-x_1),$$

and equating this to (say) ±·0005, the resulting curves are easily calculated from the equation

$$y_1 = \pm\frac{20}{x_1-24}-\frac{23}{25}x_1$$

14. In taking this step, not only was the labour in calculating the curves reduced as expected, but the curves covering the quarter-plate in question were *much fewer in number* (see fig. 2), so that the variety of separate corrections to be applied was much less. This at once suggested the third step, viz. an inquiry what part of the coefficient of y_1 in the original expression (which may be written, after multiplying by a power of 10,

$$-550x_1+7590y_1+25x_1y_1+23x_1^2)$$

should be applied separately so as to leave for diagrammatic application an expression yielding the fewest number of curves over the actual quarter-plate?

15. This is practically the following question in geometry: there is a series of hyperbolas

$$-550x+\lambda y+25xy+23x^2=\pm500\,(2n+1)$$

where n is an integer, and λ a variable parameter. Find the

Fig. 1.

FIRST FORM OF CORRECTION.

$(-55x+59y+2{\cdot}3x^2+2{\cdot}5xy)=\text{Const.}$

(Zone +26° only).

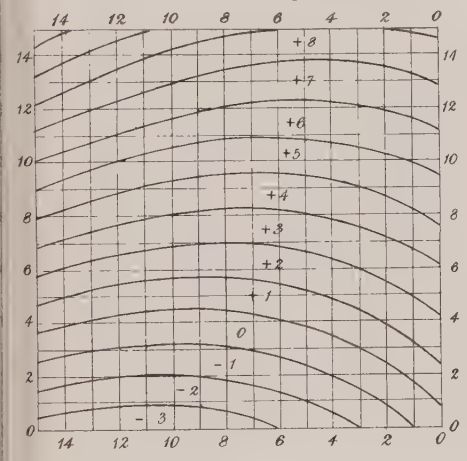


Fig 2.

SECOND FORM OF CORRECTION

$(23x+25y)(x-24)=\text{Const.}$

(Zone +26° only)

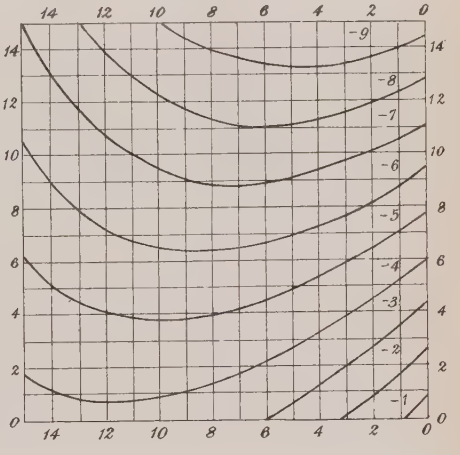


Fig. 3.

THIRD FORM OF CORRECTION

$-55x-21y+(23x+25y)x=\text{Const}$

FEW CURVES (Zone +26° only)

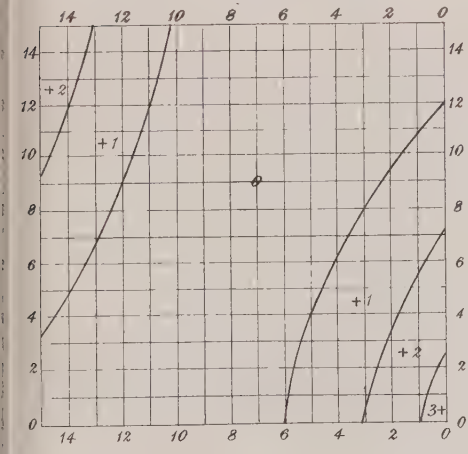
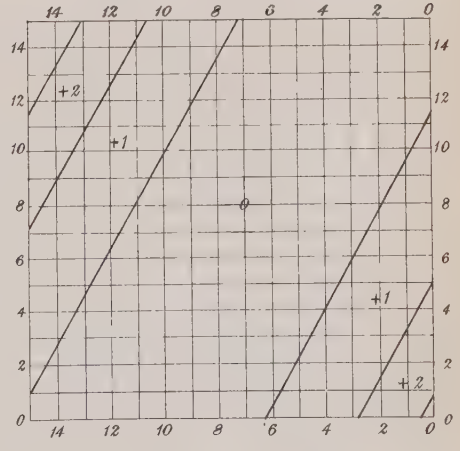


Fig. 4.

FINAL FORM OF CORRECTION.
FOR ALL ZONES.

$24\{(x-7)+\tfrac{1}{2}(y-7)\}^2=\text{Const.}$



value of λ which will make the number of curves crossing a given square

$$[x=0 \text{ to } x=14\,;\ y=0 \text{ to } y=14]$$

a minimum. It is easily seen that the common centre of the hyperbolas must coincide with the centre of the square, and we were thus led to the value

$$\lambda = -210,$$

which gives the curves shown in fig. 3. It will be seen that the number of curves is now very small, and the application of the correction can be made with very little labour indeed.

16. A fourth step which has been taken is open to criticism because of a slight sacrifice of accuracy in order to save labour. Personally, I think the sacrifice quite justifiable, but others may be of a different opinion. It is to be remarked that the processes indicated above are strictly accurate.

The fourth step consists in throwing the original expression into the form

$$\cdot 000023\left\{(x-7)+\frac{25}{46}(y-7)\right\}^2$$
$$-\cdot 000023\times\left(\frac{25}{46}\right)^2(y-7)^2$$
$$+\text{linear terms.}$$

The linear terms are to be applied separately, as will presently be mentioned. The term

$$-\cdot 000023\times\left(\frac{25}{46}\right)(y-7)^2$$

is to be *neglected*, its greatest value over the region

$$y=0 \text{ to } y=14$$

being

$$\cdot 000023\times 14=\cdot 0003$$

and this is the slight sacrifice of accuracy above mentioned.

The first term is to be diagrammatically applied, and being a perfect square its contour lines are *straight* instead of being hyperbolas, and thus very easily drawn by a ruler from two points only on each.

17. Further, it may be remarked that the coefficients ·000023 and ·000025 which occur throughout the above expressions, are the particular values of k and l for the zone + 26°; k and l being (as in *Monthly Notices*, liv. p. 11) the coordinates of the centre of one plate or another.

These coordinates are nearly equal, except for the zones where

a change in the number of plates is made ; and if we take them both ·000024 *for all zones* we shall lose very little in accuracy, and have a *single diagram for all zones.* This single diagram is shown in fig. 5. The diagrams throughout refer to the expression for $x_2 - x_1$; corresponding diagrams for $y_2 - y_1$ may easily be constructed ; and in the case of the last may be obtained by simply turning it through a right angle.

18. The application of part of the correction by any of these diagrams leaves a linear part to be applied numerically. The first three leave merely a multiple of y_1, but the fourth (which I regard as the best) leaves multiples both of x_1 and y_1. It was not until after a little experience in comparing plates that it occurred to me that these linear remainders need not be actually applied to individual measures, but may be subtracted algebraically from the linear expressions ultimately found by comparing two plates, as explained in the next paragraph. The final outcome of the paragraphs §12–§18 is thus as follows :

To the measured coordinates on the quarter-plate to be transformed apply corrections +·001, +·002 *or* +·003, *according to the diagram of fig.* 5 *for the* x *coordinate and a corresponding diagram for the* y *coordinate, the greater part of the measures requiring no correction. The measures are then ready for linear comparison with the overlapping quarter-plate.* Those who object to the slight inaccuracy of the diagram 5 should use diagram 4, which is a little more laborious to construct, but quite accurate.

19. *Deferred Application of Linear Terms.*—After the application of corrections, as in the last paragraph, we have now two quarter-plates of measures of the same stars *corrected for difference of plane of the plates*, and differing theoretically only in orientation and position in their common plane. Practically there are also discrepancies due to refraction, aberration, scale value, &c. The existence of these latter sources of difference, which have hitherto been deliberately neglected, will not sensibly affect the transformation of the last paragraph, unless the plates have been taken in serious disregard of the resolutions of the Astrographic Congress and Committee.

The measures on one plate will thus be linear functions of the measures on the other : that is, we shall have

$$x_2 - x_1(\text{corrected}) = (a + \alpha)x_1 + (b + \beta)y_1 + c + \gamma$$
$$y_2 - y_1(\text{corrected}) = (d + \delta)x_1 + (e + \epsilon)y_1 + f + \zeta$$

where α, β, γ, &c., refer to the remaining part of the theoretical expressions for transforming an ideal x_1 and y_1 into an ideal x_2 and y_2 ; and a, b, c, &c., refer to the errors of refraction, aberration, orientation, &c. In dealing with the measures of individual stars, however, there is no need to distinguish between a and α, b and β, and so on ; we may write

$$x_2 - x_1(\text{corrected}) = Ax_1 + By_1 + C$$
$$y_2 - y_1(\text{corrected}) = Dx_1 + Ey_1 + F$$

and find from the measures, by least squares or otherwise, the coefficients A, B, C, D, E, F, which we may then analyse into their constituents, a, β, γ, &c., known from theory, and a, b, c, &c., which inform us of the accidental errors. The analysis is thus performed for 6 coefficients only instead of for 50 or 100 stars—another great saving of labour.

20. *Practical Method of Solving the Equations.*—The special form of the equations has suggested a special method of dealing with them. It will be found that from three or four stars we can obtain an approximate solution of the form

$$A = E = 0,\ B = -D,\ C = C',\ F = F',$$

where, moreover, B and D are only given to three decimal places, C′ and F′ to one. Thus in the example given below, the following approximate solution was found:

$$A = E = 0,\ B = -D = -\cdot011,\ C' = 10\cdot850,\ F' = 11\cdot950$$

By means of an easily constructed table, the expressions $By_1 + C'$, $Dx_1 + F'$ can be quickly applied to the coordinates x_1 and y_1 (corrected); and their differences from x_2 and y_2 will then rarely exceed ·006, and will in general be ·000, $\pm$·001, $\pm$·002, or some very small quantity. The differences become, in fact, like residuals, and can be treated by any of the rapid methods applicable to residuals. The mean of the differences for all the stars in any portion of the plate can almost be taken mentally, and the mean coordinates of the stars on this portion (not required with great accuracy) can be estimated at sight. Thus the normal equations for a final solution can be written down very quickly, and as quickly solved. The deduced linear expressions representing the differences are also very simple, and can be easily compared with them, which completes the whole comparison.

21. *Practical Example of Reductions.*—Such a description of new processes would of course be incomplete without an example, and the following is taken from the first pair of plates compared at Oxford. Twenty-one stars have been selected from the quarter-plates 126 and 444 quite at random, as sufficient to show the method. To give the measures of the whole 85 stars common to these quarter-plates would take too much space.

The coordinates of the centres of the plates are

Plate 126 (Taken 1892 Aug. 12)	R.A. $20^h\ 8^m$	Decl. + 26°
Plate 444 (Taken 1893 Aug. 15)	R.A. $20^h\ 4^m$	Decl. + 25°

Table of reduction of Plate 126 (*S.W.*) *to Plate* 444 (*N.E.*)

x coordinate.

1. No. for Ref.	2. Measure on Plate. 444 ($=x_2$)	3. 126 ($=x_1$)	4. Small Corr. to 126.	5. Approx. Solution.	6. 126 Corrected.	7. Excess of x_2 $=\delta x_1$	8. Excess from Formula.	9. C−O.
1	24·590	13·892	+ ·002	− ·149	24·595	− ·005	− ·003	+ ·002
2	22·777	12·080	+ 2	− ·153	22·779	− 2	− 3	− 1
3	20·223	9·514	+ 1	− ·139	20·226	− 3	− 2	+ 1
4	25·188	14·439	+ 2	− ·101	25·190	− 2	0	+ 2
5	22·102	11·347	+ 1	− ·097	22·101	+ 1	0	− 1
6	19·550	8·784	...	− ·086	19·548	+ 2	0	− 2
7	18·211	7·501	...	− ·137	18·214	− 3	− 2	+ 1
8	15·940	5·220	...	− ·132	15·938	+ 2	− 2	− 4
9	14·505	3·806	...	− ·146	14·510	− 5	− 3	+ 2
10	12·972	2·241	...	− ·117	12·976	− 4	− 2	+ 2
11	14·270	3·505	...	− ·083	14·272	− 2	0	+ 2
12	18·591	7·819	...	− ·077	18·592	− 1	0	+ 1
13	15·084	4·283	...	− ·052	15·081	+ 3	+ 2	− 1
14	14·634	3·797	+ 1	− ·017	14·631	+ 3	+ 3	0
15	17·165	6·342	...	− ·032	17·160	+ 5	+ 3	− 2
16	20·120	9·299	...	− ·032	20·117	+ 3	+ 0	+ 1
17	21·424	10·601	...	− ·031	21·420	+ 4	+ 2	− 2
18	24·495	13·671	...	− ·030	24·491	+ 4	+ 3	− 1
19	24·685	13·881	+ 1	− ·050	24·682	+ 3	+ 2	− 1
20	25·469	14·687	+ 1	− ·069	25·469	0	+ 1	+ 1
21	22·466	11·680	...	− ·068	22·462	+ 4	+ 1	− 3

y coordinate.

1. No. for Ref.	2. Measure on Plate. 444 ($=y_2$)	3. Plate. 126 ($=y_1$)	4. Small Corr. to 126.	5. Approx. Solution.	6. 126 Corrected.	7. Excess of y_2 $=\delta y_1$	8. Excess from Formula.	9. C−O.
1	25·649	13·543	+·002	+·153	25·648	+·001	+·005	+·004
2	26·000	13·911	+ 2	+·133	25·996	+ 4	+ 4	0
3	24·706	12·648	+ 1	+·105	24·704	+ 2	+ 3	+ 1
4	21·328	9·213	+ 1	+·158	21·322	+ 6	+ 6	0
5	20·846	8·765	...	+·124	20·839	+ 7	+ 5	− 2
6	19·878	7·827	...	+·096	19·873	+ 5	+ 4	− 1
7	24·548	12·511	+ 1	+·083	24·545	+ 3	+ 2	− 1
8	23·982	11·971	...	+·057	23·978	+ 4	+ 1	− 3
9	25·313	13·322	+ 1	+·042	25·315	− 2	0	+ 2
10	22·606	10·630	...	+·025	22·605	+ 1	0	− 1
11	19·507	7·516	...	+·039	19·505	+ 2	+ 2	0
12	19·011	6·974	...	+·086	19·010	+ 1	+ 4	+ 3
13	16·741	4·744	...	+·047	16·741	0	+ 3	+ 3
14	13·534	1·540	+ 1	+·042	13·533	+ 1	+ 3	+ 2
15	14·963	2·933	...	+·069	14·952	+ 11	+ 4	− 7
16	14·847	2·791	...	+·102	14·843	+ 4	+ 5	+ 1
17	14·913	2·841	...	+·117	14·908	+ 5	+ 6	+ 1
18	14·830	2·722	...	+·150	14·822	+ 8	+ 8	0
19	16·592	4·482	...	+·153	16·585	+ 7	+ 7	0
20	18·433	6·314	...	+·162	18·426	+ 7	+ 7	0
21	18·261	6·172	...	+·128	18·250	+ 11	+ 6	− 5

The *first* column gives a number for reference.

The *second* column gives the measured coordinate on plate 444, N.E. quarter ; these measures are to remain untouched.

The *third* column gives similarly the measures on plate 126 (S.W. quarter), which are to be corrected to conformity with 444. We thus apply the small correction in the *fourth* column, from the diagram in fig. 5. It will be seen at once how small and simple this correction is, though, of course, quite sensible. It is sufficient to set down the correction at present ; it may be added in with column 5.

Before proceeding further we now form an approximate solution from four stars only. The four selected are (1), (9), (13), and (19), and we have

	x_2	x_1	x_2-x_1	y_2	y_1	y_2-y_1
(1)	24·590	13·894	10·696	25·649	13 545	12·104
(9)	14·505	3 806	10·699	25·313	13·323	11·990
(13)	15·084	4·283	10·801	16·741	4·744	11·997
(19)	24·685	13·882	10·803	16·592	4·482	12·110

The values of x_2-x_1 for (1) and (19) differ by ·107 ; and (in this approximate solution) this difference is to be assumed wholly due to the difference in value of y_1 (see paragraph 20).

Thus we have

$$B = -\frac{\cdot 107}{9\cdot 063} = -\cdot 0118$$

From the pair of stars (9) and (13) we should get

$$B = -\frac{\cdot 102}{8\cdot 579} = -\cdot 0119$$

Similarly from the pair (1) and (9) we get

$$D = +\frac{\cdot 114}{10\,088} = +\cdot 0113$$

and from the pair (13) and (19)

$$D = +\frac{\cdot 113}{9\cdot 599} = +\cdot 0118$$

The mean of these (numerically) is ·0117.

The values of C and F are found from the formulæ

$$C = x_2 - x_1 - By_1$$
$$F = y_2 - y_1 - Dx_1$$

and are as follows for the four stars :

	C	F
(1)	10·855	11·941
(9)	10·854	11·945
(13)	10·856	11·947
(19)	10·856	11·947

the mean values being 10·855 and 11·945.

Now it is open to us to apply these corrections as exactly as we please ; only it is to be remembered that they are not *final* and are merely meant to save labour by transforming x_1 and y_1

into numbers nearly resembling x_2 and y_2. We shall always save labour by retaining only two decimals in C and F, and only three in B and D, as above. We thus apply the corrections

$$10{\cdot}850 - {\cdot}0110 y_1 \text{ to } x_1$$

and

$$11{\cdot}950 + {\cdot}0110 x_1 \text{ to } y_1$$

The application may be performed in a variety of ways, *e.g.* by making a special table, or by using Crelle. Different methods will probably be found advantageous in different zones, for the coefficients B and D will vary considerably in magnitude.

Returning now to the table, the variable parts of these corrections are given in the *fifth* column under the heading "Approximate Solution."

In the *sixth* column the sum of columns 3, 4, and 5 is given, showing a corrected value of x_1 nearly equal to x_2.

The *seventh* column is the difference of columns 6 and 2; and gives the residual differences, which are to be discussed by the method of least squares or its equivalent. The process of approximate correction previously applied in no way invalidates the application of the rigorous method of least squares if it should be deemed advisable to use it; but the following process (due to Mr. Dyson) will probably be found sufficient, and is much shorter and simpler:

Stars 1 to 6 have $x_1 > 7$, $y_1 > 7$
„ 7 „ 11 „ $x_1 < 7$, $y_1 > 7$ (approx.)
„ 12 „ 15 „ $x_1 < 7$, $y_1 < 7$ (approx.)
„ 16 „ 21 „ $x_1 > 7$, $y_1 < 7$

The *sums* of these groups give

No. Stars.	x_1	y_1	δx_1	δy_1
6	70·0	65·9	−·009	+·025
5	22·3	56·0	−·012	+·008
4	22 2	16·2	+·010	+·013
6	73·8	25·3	+·012	+·042

whence we obtain quickly the *mean* quantities for the N. half of the plate, the S. half, the E. half, and the W. half as follows:

N. half	8·4	11·1	−·0019	+·0030
S. half	9·6	4 2	+·0022	+·0055
E. half	12·0	7·6	+·0003	+·0056
W. half	4·9	8·0	−·0002	+·0024

These give four pairs of equations, the first pair being

$$8{\cdot}4a + 11{\cdot}1b + c = -{\cdot}0019$$
$$8{\cdot}4d + 11{\cdot}1e + f = +{\cdot}0030$$

and these are readily solved. We first find

$$a = +{\cdot}00004,\ b = -{\cdot}00053$$
$$d = +{\cdot}00047,\ e = -{\cdot}00025$$

and substituting these in the four pairs of equations, we obtain the following values for c and f:

c	f
+·0039	+·0018
+·0039	+·0019
+·0038	+·0017
+·0039	+·0021

a sufficiently good accordance. The numerical values of the expressions

$$+{\cdot}00004x_1 - {\cdot}00053y_1 + {\cdot}0039$$

and

$$+{\cdot}00047x_1 - {\cdot}00025y_1 + {\cdot}0019$$

were taken out from a simple diagram, and are entered in the *eighth column* of the table. The differences between these theoretical expressions and the observed differences in column 7 are shown in the *ninth column.*

These final residuals rarely exceed ·002 numerically (= 0″·6). On examining the measures which give larger residuals it is generally found that a careful remeasure made the discrepancy disappear. The residual ·007 in the y coordinate is owing to a mistake of ·010 ; and this might have been suspected and corrected earlier. But as the present example is intended rather to illustrate the *method* than to show the final accuracy attainable (which will no doubt improve with practice), the figures have not been altered. The measures were, as above remarked, the first made at Oxford with a scale ; and were, moreover, made with a wooden model of the apparatus with coarse screws for slow motions, while Mr. Simms was making the finished apparatus. But even under these conditions the mean residual is only $\pm$ ·0016 for x and $\pm$ ·0017 for y.

The final formulæ for the reduction of x_1 and y_1 to accordance with x_2 and y_2 are thus :

$$\begin{aligned} x_2 - x_1 &= -{\cdot}011y_1 + 10{\cdot}850 \\ &\quad + {\cdot}00004x_1 - {\cdot}00053y_1 + {\cdot}0039 \\ &= +{\cdot}00004x_1 - {\cdot}01153y_1 + 10{\cdot}8539 \\ y_2 - y_1 &= +{\cdot}011x_1 + 11{\cdot}950 \\ &\quad + {\cdot}00047x_1 - {\cdot}00025y_1 + {\cdot}0019 \\ &= +{\cdot}01147x_1 - {\cdot}00025y_1 + 11{\cdot}9519 \end{aligned}$$

Now the theoretical expressions, due to the ideal geometrical conditions, are

$$x_2 - x_1 = -\cdot00006x_1 - \cdot00753y_1 + 10\cdot8849$$
$$y_2 - y_1 = +\cdot00753x_1 + \cdot00005y_1 + 11\cdot9436$$

and thus the expressions representing refraction, aberration, orientation error, &c., &c., are

$$x_2 - x_1 = +\cdot00010x_1 - \cdot00400y_1 - \cdot0310$$
$$y_2 - y_1 = +\cdot00394x_1 - \cdot00020y_1 + \cdot0083$$

22. In the foregoing paragraphs I have endeavoured to show how, if the rectilinear coordinates of stars on two overlapping photographic plates are measured by a simple and rapid process, they may, also by a simple and rapid process, be compared. Further, that in the case of two plates taken at an interval of 12 months, the comparison shows that there is nothing seriously wrong with any of the measures : that in the case of twenty-one stars taken at random, and measured with a new and rough apparatus by unskilled measurers, the differences rarely exceed ·003 (= 0″·9). It needs no further comparison with known places to show that in measuring photographic plates in this way we are measuring something real and tangible. It is certain that we can arrive at results which compare favourably with meridian observations by processes similar to that above indicated. And even by such processes the measurement and reduction of the plates will take *far longer* than the obtaining of them.

On the other hand, if we aim at a higher order of accuracy, consider how many different sources of error must be carefully investigated. The following list is, if anything, incomplete :

Errors of the *réseau*, errors of the measuring screw or scale, errors in raising figures, distortion of the film, curvature of the plate, optical distortion of the lens, personality in bisecting images, centring of elongated images, proper motions of the stars, to which may be added the accidental errors naturally appertaining to more complicated calculations. Most of these, if not all, must be separately investigated if we aim at a higher order of accuracy than is above indicated ; and it would seem doubtful, not only when the work would be finished, but when we should be in a position to commence it.

23. If it occasions surprise that the necessity for some simple and rapid process should be so strongly insisted on, I would briefly call attention to the following facts and figures :

The first tentative proposals for measuring the plates were made in the first number of the *Bulletin du Comité Permanent* (1888 March), by Dr. Gill. They were necessarily quite tentative, and their main object was to initiate a discussion. Dr. Gill mentions three methods of procedure —

(1) The method of rectangular coordinates (*i.e.* that which forms the basis of the present paper).
(2) The method of distance and position-angle.
(3) The parallactic method of measuring R.A. and Declination direct.

That Dr. Gill should immediately dismiss the first method with the comment "that it is much inferior to the second, and does not even offer the advantages of easy reduction," is merely (if I may be allowed the expression) an indication that we have learnt something in the last six or seven years. M. Bakhuyzen ventured to differ from Dr. Gill soon afterwards.

Dr. Gill proceeded to propose a scheme for measurement, involving a permanent Bureau Central, with a staff of twenty-two people, and a budget of 250,000 francs per annum, at least. I took some share in opposing this scheme as too impractical, because of its magnitude. It aimed at getting the most out of the plates possible: it was a *maximum* programme. But the principle of limiting work to what can be accomplished, instead of aiming at what we should hope for, is not new. In meridian work, for instance, observations are limited to three for each star, though a much greater accuracy could be got by making more. The object of the present paper is to suggest a *serious* limitation of the work, without so seriously diminishing its value.

As a second term of comparison we may take the facts given in the published Report of the Paris Observatory for 1893. Mdlle. Klumpke, with a staff of four ladies, measured seventy-two plates in the year on the plan developed with considerable skill by M. Lœwy and MM. Henry. At this rate it will take the Paris Observatory *eighteen* years to measure the 1,300 plates taken at Paris alone. But the Paris Observatory is a strong one, one of those that should quickly finish their own work and help others; it can devote five people specially to the work of measurement. The whole staff of the Oxford Observatory consists of three people, including myself—for University work, taking the plates, and measuring. How much longer then shall we take on such a plan to measure and reduce our plates?

Some serious curtailing of the work is necessary; push the curtailing indicated above as far as it will go, and I believe the work will be found to strain the utmost energies of the astronomical world to get it done in reasonable time. I may, perhaps, without further explanation, conclude this paper with an indication of a

Minimum Programme.

(1) Measure, by referring to the *réseau* lines, *one* bisection of *one* image per star, about 200 stars per plate (100 would be better). Record the measures as simply as possible.

(2) Put almost all reductions aside with a view to getting

these measures completed for the whole area assigned to your observatory within as few years as possible. We have no information how long photographic plates will last. The reductions have been shown to be simple.

(3) When opportunity offers, compare plates by the above method so as to see that no serious error has crept in accidentally. Ordinarily the plates are good enough if they can be measured.

On the Need and Usefulness of Co-operation in Meridian Observation. By Truman Henry Safford.

The following paper grew out of my own experiences. I had for a good while employed my rather scanty leisure for observation in preparing a catalogue of polar stars which had been or could be employed as standards; had published a portion of the right ascensions reduced to 1885, and was desirous of filling up gaps in observing—time, due to the completion of the original project in certain hours of right ascension.

Originally I intended to obtain trustworthy places of all stars to $7^{m}\cdot5$ inclusive within 10° of the North Pole, and all other stars which had been regularly used as standard polars. The latter class are usually brighter than $7^{m}\cdot5$, and are more numerous than one would imagine; but at Oxford fainter stars had been also used as standard polars, and in some cases by Mr. Carrington and others.

The enlargement of the working list which at once presented itself as desirable was one which should give accurate positions of four to six stars to every four square degrees within 10° of the pole. By using Lœwy's method of tying the zero-points of neighbouring plates together, the number just mentioned will give the zero-points for the centres of the plates, and the scales will be determined by the overlapping portions common to two plates.

In some parts of the sky, as every observer well knows, bright stars are much less numerous than elsewhere, so that these portions require the meridian observation of fainter stars. There are, for example, portions of *Orion*, where the Radcliffe Catalogue for 1890, containing all 7th magnitude stars, furnishes six stars or more to the square degree. In the same region Professor Valentiner has observed all stars down to $8^{m}\cdot0$ between the equator and 8° of south declination; his catalogues will furnish the required number for additional areas, where stars of 7th magnitude are too few. His scale of observation is rather more minute than Mr. Stone's, and his results depend quite uniformly on six observations, part of which are unpublished. Meanwhile the Astronomische Gesellschaft is carrying on its survey, to include all stars to $9^{m}\cdot0$, and all fainter which have been

previously observed by certain specified astronomers; and we thus have, for the region of Schoenfeld's Durchmusterung, almost everywhere materials enough for the photographic zero-points.

This is not quite so in the northern hemisphere. The Astronomische Gesellschaft's survey dates (on the average) twenty years back. In order to avoid the necessity of extrapolating the proper motions up to 1900, it will be necessary to re-observe a sufficient number of stars.

The consideration of the required accuracy at once relieves us of the fear that meridian observation will become a thing of the past. The probable error of a star's position on a photographic plate is not much more than a tenth of a second in either coordinate, if the necessary precautions are taken; and this is very nearly equal to the probable error which M. Lœwy found, to his regret (*Comptes Rendus*, cxvi. 710: April 4, 1893), for the position of the centre of a plate derived from twenty-six stars in four areas. The large probable error is due to extrapolation, or the assumption of zero proper motion. It would be somewhat diminished by using the stars of the Astronomische Gesellschaft, but still more by re-observation.

The following results may be interesting in this connection. In 1892 I prepared a catalogue of 627 stars in declination for the Mexican Boundary Commission. The positions were of course extrapolated, and all the good catalogues I could find were used. If the star was one of Bradley's, the proper motion given by Professor Auwers was usually accurate enough, and could be tested by intermediate observations. If it was only found in Lalande's or Bessel's zones, before it had been observed in a more deliberate way, it was frequently necessary to discard the star, even when it made an excellent companion (in a pair for the zenith telescope) to a well-known star of Bradley's. The stars actually employed gave probable errors in declination, from $\pm 0''.1$ up to $\pm 0''.5$, as calculated rather rigidly, with a fair allowance for unexpected sources of error. But these were of the 6th magnitude or brighter; and the largest probable errors were due to uncertain proper motion.

The Coast and Geodetic Survey sometimes use declinations of similar stars, when probable errors are larger than this, even up to $1''$, because in their work the star can be re-observed, if need be, before the final reduction. This is not usually possible in establishing a boundary.

What, then, is the probable error of a determination by four good observations? I assume that the division errors will be rendered harmless by using the instrument in different positions or shifting the microscopes, or by employing more division lines. The objection that there is too great accumulation of small errors in employing the differential method is one which is rapidly disappearing; and thorough ventilation of observing-rooms and truly central field illumination, with great care on the observer's part, and good instruments, now make much more accurate individual observations possible.

The probable error of one such need not be more than $\pm 0^s.03$ $\pm 0''.4$ with a good instrument; and allowing something for constant error, the mean of four observations need not have a greater probable error than $\pm 0^s.02$ $\pm 0''.25$ if sufficient care is taken.

With six stars to a photographic plate, each determined by two independent instruments with this accuracy, the probable error of the centres would be sensibly less than $\pm 0''.10$ in either coordinate, and the combination with the older observations would be favourable, and still farther diminish the probable errors.

The dangers arising from the use of the differential method need to be minimised by a large catalogue of secondary fundamental stars, and their determination will be facilitated by the latest improvements in instruments and observing. The errors of division of all the single lines or diameters are rarely determined; but it is possible with many instruments to change the circle on the axis. This has been done at Washington regularly, for a quarter of a century, so that the ordinary *Nautical Almanac* stars are quite freed from this source of error. Flexure is more troublesome with large instruments; but the Repsolds have succeeded in nearly getting rid of it by carefully calculated symmetry in their instruments; and the exchange of object-glass and eyepiece, while it may not eliminate flexure entirely, certainly gives two independent flexures, which probably have contrary signs.

The problem of ascertaining primary star-places by direct comparisons with the Sun, and independent determination of refraction flexure, &c., will certainly afford occupation for a number of astronomers for a good many years. But independent primary catalogues are now more numerous and agree better than formerly; and the efforts now being made will doubtless render them far more available for observatory use.

The fact is that the photographic catalogue plates set the standard of meridian observation higher than any former process of astronomy requires. The zero-points of the plates must be very accurately established. This requires the observation of many small stars, with great precision; this again reacts upon the needful accuracy of the many standard stars which are not of first importance; and this again requires that the fundamental brighter stars, which can be well observed by day, shall be fixed with the last degree of care. An accuracy which does not now meet a pretty high standard is but of little use.

In conclusion, I desire to say that Mr. Gill's suggestion for a convention in 1896 seems a good one. If such a convention can be held it would be a benefit, not only to the astronomers of large observatories, who have ample means, but in this country at least to a good many who are limited in their power of effecting large results by scantiness of means, frequently involving many other duties. Practical astronomy is now taught in a good many of our colleges, and those who learn it occasionally accom-

plish some scientific work. But the instructors themselves need to practise the art they are teaching; and are gradually acquiring the instruments, and in some small degree the leisure, which is necessary. It would be a great benefit to them if they could be so brought into contact with better observers that they could measure themselves against them. And a congress as suggested by Mr. Gill would powerfully stimulate the progress of accurate observing in this country. If, however, such a congress cannot be organised, it is to be hoped that the subject of distribution of meridian observation and its arrangement to avoid waste of labour will be thoroughly discussed by the masters of that subject.

The *British Association Catalogue*, now a scarce and costly book, has been of much benefit, and has done some injury. Its convenience made it a good working list; but its incompleteness, even as to naked-eye stars, prevented a good many astronomers from observing such as were fainter than those it included, or had been accidentally omitted, though bright enough. Thus it happens that the existing star catalogues do not yet completely meet even the wants of field astronomers using portable instruments.

The problem of comet observations with equatorials will most readily be solved when the stars near the paths of these bodies have been photographed, and their places can be fixed with great accuracy.

The principle which seems to me the best in choosing objects for meridian observation of the stars is to classify them according to magnitude.

1^m–$4^m{\cdot}0$	Struve's primary stars.
$4^m{\cdot}0$–$6^m{\cdot}5$	Secondary stars, to be regularly and precisely determined.
$6^m{\cdot}6$–$7^m{\cdot}5$	Tertiary stars, to be observed with more regularity than they have been.
$7^m{\cdot}6$–$8^m{\cdot}5$ and $8^m{\cdot}6$ and fainter	When necessary for photographic zero-points and other purposes.

Each class should be observed with greater accuracy and more care than the following, because in general more important; and stars of 6th and brighter magnitudes should be the standards for the determination of telescope.

As, however, these are largely opinions based on an experience narrow in certain directions, I venture to suggest the usefulness of fully discussing the instruments, the methods, the organisation, the resulting accuracy, and the attainable and desirable accuracy of meridian work. The evil to be avoided is the continuance of any such ancient routine methods as hinder the attainment of the precision desirable.

Williamstown, Mass.:
1894 *December* 28.

On the Effect of Atmospheric Dispersion on the position of a Star.

By Professor Arthur A. Rambaut, M.A., Sc.D.

In these days of extreme accuracy in astronomical observations any effect, however small, that will influence the results cannot be overlooked. For this reason, my attention having been recently directed to the necessity of increasing the constant of refraction as determined by Bessel when it is desired to apply it to the correction of photographic measures (v. *Astronomische Nachrichten*, No. 3255), I have been at considerable pains to ascertain how far it may be necessary to take into account the character of the light of a star in computing the refraction by which it is affected in the case of visual observations.

In a paper by Stephen Lee, published in the *Phil. Trans.* of the Royal Society as early as 1815, the effect of the difference in colour of two stars has been in a general way pointed out, and some observations made by him on the planet *Mars* are described. His observations were, however, wanting in the precision necessary to such a delicate research, and led to no very definite numerical results.

His paper, however, seems to have attracted some attention at the time, and was translated by Professor Brandes, of Breslau, for Bode's *Astronomisches Jahrbuch* for the year 1819.

But although it is obvious when pointed out that the constant of refraction applicable to any particular star will depend on the character of its spectrum, I think it has been very generally assumed that the effect of a difference in the light of two stars will, under any circumstances likely to occur in practice, be so small as to be quite insensible. It has hitherto in all cases, so far as I am aware, been taken for granted that the Besselian formulæ for the differential refraction fully correct for this effect, and that any uncertainty which may exist as to the exact value of the coefficient of refraction has no effect on the resulting measures, since the differential is, in general, such a small proportion of the total refraction. This would undoubtedly be true were the coefficient of refraction always the same for both stars, for even if there were a doubt, amounting to as much as one-fiftieth of the whole, it would but rarely make itself felt in differential measures.

It is, however, quite otherwise if the coefficient is to be considered different for two stars in close proximity to one another. For if the coefficient for one of the two stars exceeds that for the other by a certain fraction of its whole amount, the outstanding correction, which the Besselian formulæ fail to take account of, is the same fraction, not of the differential, but of the absolute refraction affecting the star, and this, even at moderate zenith distances, may easily in certain cases become comparable with, or largely exceed, the correction for the

differential refraction. In fact, the refraction for light of a particular wave-length being denoted by the expression

$$\alpha\,(\mathrm{BT})^{\Delta}\gamma^{\lambda}\tan\zeta,$$

or simply $\beta \tan \zeta$, where β is a function of ζ, if the coefficient of $\tan \zeta$ for another star is different, we shall have the refraction in its case denoted by

$$(\beta' + d\beta)\tan\zeta',$$

where β' is the value of β corresponding to the zenith distance ζ', and $d\beta$ the correction for a difference of refrangibility.

Now the first part only of this, namely, $\beta' \tan \zeta'$, is taken account of by Bessel's formulæ. There will thus be the part $d\beta \tan \zeta'$ still outstanding, which will affect the difference between the zenith distances of the two stars by its whole amount.

With the object of ascertaining the order of magnitude to which this outstanding difference can attain I remark that, if μ is the refractive index of air for any particular ray, and if β is the corresponding coefficient of refraction, we have approximately

$$\beta = \frac{\mu^2 - 1}{c\rho},$$

where ρ is the density of the air and c a constant. Hence for any two particular rays, μ and μ_0, we have

$$\beta - \beta_0 = \frac{\mu^2 - \mu_0^2}{\mu_0^2 - 1}\beta_0;$$

or, since μ and μ_0 are both very nearly equal to unity, we may write

$$d\beta = \frac{d\mu}{\mu_0 - 1}\beta_0.$$

If we imagine two monochromatic stars, both of which are orange, but such that the light of one corresponds to the red end, and that of the other to the green end of the orange, we may put

$$\mu_0 - 1 = 0{\cdot}00029508; \qquad d\mu = 0{\cdot}00000114;$$

and we have

$$\beta_0 = 57''{\cdot}682;$$

whence we find

$$d\beta = 0''{\cdot}222,$$

or multiplying by $\tan \zeta$ we get the following corresponding values :—

ζ	$d\beta \tan \zeta$.	ζ	$d\beta \tan \zeta$.
30°	0″·13	60°	0″·39
45	0·22	75	0·83

Of course the light of the stars is not monochromatic, nor does the difference between the brightest parts of their spectra in most cases correspond to as large a value of $d\mu$ as that I have assumed ; but the quantities given above show at least that in delicate researches, such as annual parallax or the relative proper motion of stars, the effect of a possible difference in the refrangibility of their light ought not to be overlooked. I would also point out that this effect is not dependent upon the distance apart of two stars, but affects the relative position of two very close stars, quite as much as of two very distant stars ; and this might in many cases help to explain a systematic difference depending on hour angle, which seems to affect the position angles of double stars as determined by many observers. For if the two components differed in colour as much as we have supposed above, a relative displacement such as that found in the little table would certainly affect the position angle of a close companion very largely, and might in extreme cases even put it into a different quadrant. And although in general the colours of stars may not differ to the extent I have supposed above, yet occasionally, and especially amongst the binary pairs, we find components so strongly contrasted in colour that some effect such as I have indicated must make itself felt.

It may perhaps be objected that, if the dispersion I refer to is sufficient to affect measures of position, then the image of each star ought to appear in the form of a small spectrum. But this effect does take place to a certain extent at all altitudes, and in the neighbourhood of the horizon becomes quite noticeable. Bouguer, in 1729, was the first to notice this atmospheric dispersion Sir W. Herschel, in 1785, and Stephen Lee, in 1815, tried to measure its amount. Robinson found that the image of *α Lyræ* at its lower culmination at Armagh measured 22″ in a vertical direction. F. Struve found a similar extension of the image of *α Piscis Australis* at its culmination above the horizon of Dorpat, and concluded that the atmospheric dispersion is about $\frac{1}{100}$th of the refraction, but that the faintness of the extreme colours renders the spectral character of the images inconspicuous at altitudes above 30°. In 1838 Bessel made some heliometer measures of the image of *α Piscis Australis*. These are discussed by Montigny in the *Bulletins de l'Académie de Belgique*, 1867, and he concludes that the observed dimensions of the image agree with those which might have been calculated by means of the indices of refraction.

Even in the case of two stars whose light is intrinsically of the same character, a marked difference of brightness would in all probability affect the measures of their relative position in the same way, if not to the same extent. For in almost all cases measures of precision are made in the field of a telescope which is illuminated by white or yellow light. Now the appearance of a bright star will not be sensibly affected by such an illumination, but if a very faint star is under examination, it is

the bluer rays that will distinguish it from the rest of the illuminated field, and the image will be formed at the place occupied by these rays in the little spectrum into which the light of the star is dispersed by the atmospheric refraction. We should thus expect to find that for the fainter stars a slightly larger coefficient of refraction would be necessary.

With the object of determining whether the difference of colour in so strongly contrasted a pair as the two components of β *Cygni* would make itself felt, I have taken a number of measures of this pair at different zenith distances, which show clearly a systematic difference affecting the distance between them of the sort, and in the direction, that theoretical considerations indicate. The observations were taken under very indifferent circumstances with regard to definition and steadiness, and for the most part on the western side of the meridian, so that the effect of colour is not so distinctly shown as it would be by a comparison of measures made at considerable distances from the zenith on both the eastern and western sides. I have, however, commenced a series of measures of γ *Andromedæ* which when complete will, I hope, be even more conclusive.

The observations were made with the Pistor and Martins micrometer attached to the 12-inch refractor, using a power of 300 in all cases.

If we denote by β the coefficient of refraction corresponding to the principal star, and by $\beta(1+\lambda)$ that corresponding to the companion, the effect of difference of colour is to diminish the zenith distance of the latter by the amount $\lambda\beta \tan \zeta$, or since the variation in β will have quite an insensible effect on $\lambda\beta$, we may write this $x \tan \zeta$.

Hence if d, p are the apparent, and d', p' the true, distance and position of the companion, and if q is the parallactic angle, we have

$$d = d' + x \tan \zeta \cos (p-q)$$

and

$$p = p' - x \tan \zeta \sin (p-q)/3600 \sin d,$$

d, d', and x being expressed in seconds of arc and p, p' in degrees.

The effect of the coefficient of refraction, β, on the two stars has been corrected by means of the ordinary formulæ in which d_0 and p_0 denote the observed values, viz. :

$$d = d_0 + \beta d_0 \{\tan^2 \zeta \cos^2 (p-q) + 1\} = d_0 + \Delta d,$$

and

$$p = p_0 - \beta \{\tan^2 \zeta \sin (p-q) \cos (p-q) + \tan \zeta \sin q \tan \delta\}/3600 = p_0 + \Delta p.$$

By means of these formulæ the following table was computed for Δd and Δp :

Sid. Time.	Δd.	Δp.	Sid. Time.	Δd.	Δp.
h	″	′	h	″	′
12	+0·009	+1·5	20	+0·011	−0·2
13	·010	1·4	21	·012	0·3
14	·010	1·1	22	·015	0·4
15	·010	0·7	23	·020	0·6
16	·010	0·4	24	·029	1·0
17	·011	+0·2	1	·051	1·7
18	·011	0·0	2	·141	3·6
19	·011	−0·1			

A complete observation consisted of two readings of the parallel followed by three determinations of the position angle, after which four settings for distance were made.

The wires were then reversed, four more settings of the wires in the reversed position were made, followed by three readings of the position angle, and finally two more determinations of the parallel.

When corrected for refraction from the preceding table they become—

No.	Date. 1894.	Sid. Time. h	m	Dist. ″	Position. °	Weight.	Definition.
1	Aug. 3	20	0	34·695	55·185	1	Good at first, but worse towards end.
2	21	21	20	...	54·883	1	Through clouds.
3	Sept. 2	20	35	·403	54·935	½	Most unsteady.
4	2	21	46	...	54·923	1	
5	4	21	24	·564	55·028	1	Definition bad.
6	4	0	13	·756	54·882	1	
7	4	0	55	·662	...	1	
8	4	1	15	·721	...	1	
9	6	18	55	·487	55·315	1½	Splendid.
10	6	23	21	...	55·145	½	
11	6	0	27	·766	...	1	Fair.
12	8	18	53	·711	55·038	½	Poor.
13	8	0	7	...	[55·107]		Definition awful. Stars like balls of wool.
14	13	0	12	·661	55·457	1	Much fog.
15	27	1	26	·972	54·907	1	Bad, but readings fairly accordant.
16	29	20	20	·660	55·008	1	Fair, but unsteady.
17	29	0	34	·822	55·283	1	Fair at first, but disimproved towards end.
18	Oct. 1	20	37	·489	54·987	1	
19	1	0	42	·673	54·967	1	

An examination of the results obtained on September 4, 6, 29, and October 1, when observations at widely different hour angles, but otherwise under similar conditions, were possible,

shows at once a tendency in the distance to increase as the star approaches the western horizon. The measures of position I found exceedingly difficult on most occasions in consequence of the unsteadiness of the images, and they are affected by such large accidental errors as completely mask any systematic law of variation.

The distances give us fifteen equations of the form

$$d' + x \tan \zeta \cos (p-q) = d.$$

Hence, if we put

$$d' = 34''{\cdot}500 + w$$

and take

$$\tan \zeta \cos (p-q)$$

from the following table

Sid. Time. h m	$\tan \zeta \cos (p-q)$.	Sid. Time. h m	$\tan \zeta \cos (p-q)$.
18 26	+0·144	23 26	+1·178
19 26	0·275	0 26	1·643
20 26	0·430	1 26	2·399
21 26	0·619	2 26	3·886
22 26	0·858		

and if we arrange the observations according to the sidereal time at which they were taken, we obtain the equations :

No.			Weight.	Res. I.	Res. II.
12	$w + 0{\cdot}21\ x$	$-0''{\cdot}211 = 0$	½	−0·101	−0·040
9	+0·21	+0·013	1½	+0·113	+0·184
1	+0 37	−0·195	1	−0·080	−0·024
16	+0·42	−0·160	1	−0·041	+0·011
3	+0·47	+0·097	½	+0·220	+0·268
18	+0·47	+0·011	1	+0·134	+0·182
5	+0·62	−0·064	1	+0·073	+0·107
14	+1·55	−0·161	1	+0·058	+0·010
6	+1·55	−0·256	1	−0·037	−0·085
11	+1·68	−0·266	1	−0·036	−0·095
17	+1·79	−0·322	1	−0 082	−0·151
19	+1·84	−0·173	1	+0·071	−0 002
7	+2·02	−0·162	1	+0·098	+0 009
8	+2·25	−0·221	1	+0·060	−0 050
15	+2·40	−0·472	1	−0·178	−0·301

Solving these by the method of least squares, we find

$$w = +0''{\cdot}082 \qquad \text{Weight } 4{\cdot}245$$
$$x = +0{\cdot}088 \qquad \text{,, } 8{\cdot}853$$

and the probable error of a single observation is

$$r = \pm 0''{\cdot}0706.$$

The residuals given by this solution are exhibited in the column headed Res. I.

If we neglect the correction x, and simply take the mean of all the observations with the weights given above, we find

$$w = +0''.171$$

and

$$r = \pm 0''.0922.$$

This solution is inferior to the first for the double reason that it gives a larger probable error of a single observation, and also that the residuals, which will be found in the last column, show a very sharp division into two groups, the positive residuals with one insignificant exception corresponding to the smaller coefficients of x, while the negative residuals with the exception of the first and twelfth observations, both of which were unsatisfactory, are to be found at the end of the table. The residual, too, given by the last equation, amounting to $0''.301$, is scarcely admissible.

That the effect of such a correction is not inconsiderable appears from a comparison of the two values of w given by the two solutions which lead respectively to the two values of the distance $34''.582$ and $34''.671$.

From the equation

$$d\beta = \frac{d\mu}{\mu_0 - 1}\beta_0,$$

or

$$d\mu = \frac{d\beta}{\beta_0}(\mu_0 - 1),$$

$d\beta$ being equal to x, we find

$$d\mu = \frac{0''.088}{57''.682} \times 0''.00029508 = 0.00000045;$$

or a difference in the refrangibility of the light of the stars less than one-half (0·4 times) the difference between the D and E lines of the spectrum would account for the whole phenomenon.

In this case perhaps it may be a matter of surprise that the difference should not prove to be greater than it actually does, the principal star being of a golden yellow, and the companion of a distinctly blue, colour. But even the blue companion contains a great deal of orange and yellow light, which in consequence of the brightness of the star will go far towards diminishing the effect at present under consideration.

The observations of γ *Andromedæ*, so far as they have at present proceeded, indicate that in the case of this star, too, there is a systematic difference of the same sort affecting the measures. The following table contains the measures of the distance, corrected for the ordinary differential refraction and

arranged in order of the sidereal time at which they were made, with the corresponding values of tan $\zeta \cos (p-q)$:

No.	Date.	Sid. Time.	Dist.	tan $\zeta \cos (p-q)$.	Definition.
		h m	"		
1	Sept. 15	18 56	10·143	−0·477	Very good at first, but disimproving.
2	27	19 54	·244	·495	Unsteady throughout.
3	8	20 2	·178	·490	Fair.
4	Oct. 2	20 5	[·028]	·490	Very bad. Observations very difficult and tedious.
5	Sept. 6	22 3	·190	·363	Poor. Images unsteady.
6	4	22 44	·148	·296	Middling.
7	8	23 11	·253	·255	Bad. Most unsteady.
8	Oct. 1	23 15	·254	·244	Fair, but a little unsteady.
9	Sept. 27	23 47	·204	·177	Exquisite, but images a little unsteady.
10	Oct. 21	0 45	·332	−0·068	Very good.

It will be noticed that in this series, with the exception of the second observation, in which the star images were most unsteady, the distance tends to increase as the star approaches the meridian. This is what we should expect from the values of tan $\zeta \cos (p-q)$. In the case of *β Cygni*, on the contrary, the larger measures corresponded to larger hour angles, the observations being made on the western side of the meridian. Unfavourable weather has, however, hitherto prevented me from getting measures of *γ Andromedæ* in this position.

It is in parallax measures that we should expect this effect to become most conspicuous, as we are in this class of work nearly always engaged in measuring the position of a fairly bright star with regard to fainter ones in its neighbourhood, and the hour angle of the star at the time of observation will, in general, range through 90° or more on each side of the meridian. Accordingly, while the observations of *β Cygni* and *γ Andromedæ* were in progress I examined the measures of 61 *Cygni*, made at this observatory by Sir Robert Ball in the years 1877 and 1878. I have selected this series rather than the later and more complete series published in the Fifth Part of *The Dunsink Observations and Researches*, in part deliberately and partly in consequence of a misconception. In the first place the very shortness of the first series, leading as it did to practically the same value of the parallax as the longer one, recommended it to me for a first investigation, and in the second place I was under the impression that the longer series consisted of measures, not of the difference of declination, but of the distance of the two stars, which would

have necessitated much longer work in computing the factors for x.

In the Third Part of *The Dunsink Observations and Researches* Sir Robert Ball gives thirty-six measures of the difference of declination between the preceding component of 61 *Cygni* and a faint (9·5 mag.) star north following, from which he deduces a parallax of 0″·465.

In the case of measures of the difference of declination we must put $p=0$, whence we find the effect on such measures of a difference of refrangibility in the light of two stars to be

$$x \tan \zeta \operatorname{ccs} q.$$

But

$$\tan \zeta \cos q = \cot (\delta + m),$$

where m is the quantity which Bessel denotes by N. We thus find for the outstanding part of the refraction in declination the expression

$$x \cot (\delta + m).$$

In Sir Robert Ball's treatment of the equations of condition furnished by the observations he introduces a correction

$$[9\cdot92224]\ \kappa \sin (58^\circ\ 17' + \odot),$$

for a possible difference (κ) in the constant of aberration corresponding to the two stars. But as there appears to be no physical reason for the existence of such a difference, I have omitted it in the solution which follows. It will therefore be understood that I have not introduced an additional unknown quantity into the equations, which would, of course, help to diminish the residuals, and therefore the probable error of an observation, but have substituted, in place of a correction which is not likely to have any real physical meaning, another quantity which must exist, whether it is large enough to be sensible or not.

In five of the observations the sidereal time is not published, but I have in two cases been able to supplement this datum from the original observing books. In three cases, however, this quantity does not appear to have been observed—namely, in the tenth, seventeenth, and thirtieth observations—and I have accordingly been obliged to omit them. All the other observations have been included with the weights assigned by Sir Robert Ball. I thus obtain the following equations of condition in which the mean difference in declination is taken equal to $67''\cdot150 + w$; the proper motion is assumed to be $3''\cdot232 + y$, $d\zeta$ is denoted by x and π (the parallax) by z:

No.	Equations of Condition.				Weight.	Residuals.
				"		"
1	$w + 0.276\,x$	$-0.496\,y$	$-0.801\,z$	$+0.271 = 0$	...	-0.044
2	$+0.401$	-0.489	-0.814	$+0.251$	...	-0.063
3	$+0.306$	-0.453	-0.847	$+0.411$	...	$+0.079$
4	$+0.369$	-0.445	-0.849	$+0.223$	$\frac{1}{2}$	-0.108
5	$+0.346$	-0.440	-0.849	$+0.248$	...	-0.084
6	$+0.276$	-0.409	-0.833	$+0.352$	...	$+0.023$
7	$+0.330$	-0.388	-0.803	$+0.283$	...	-0.033
8	$+0.279$	-0.335	-0.674	$+0.191$	...	-0.075
9	$+0.279$	-0.327	-0.648	$+0.455$	...	$+0.199$
10	[...]	-0.278	-0.452	$+0.208$	...	[...]
11	$+0.789$	-0.261	-0.377	$+0.249$	...	$+0.122$
12	$+0.583$	-0.251	-0.324	$+0.262$	...	$+0.148$
13	$+0.901$	-0.231	-0.229	-0.154	...	-0.217
14	$+0.644$	-0.209	-0.116	$+0.137$	$\frac{1}{2}$	$+0.108$
15	$+0.327$	-0.191	-0.018	-0.045	...	-0.049
16	$+0.710$	-0.185	$+0.014$	$+0.129$	...	$+0.154$
17	[...]	-0.174	$+0.070$	-0.219	...	[...]
18	$+0.567$	-0.163	$+0.128$	-0.150	...	-0.086
19	$+0.609$	-0.133	$+0.282$	-0.194	...	-0.067
20	[...]	-0.048	$+0.633$	-0.551	...	[...]
21	$+0.918$	-0.046	$+0.641$	-0.324	...	-0.041
22	$+1.791$	-0.040	$+0.669$	-0.332	...	0.000
23	$+1.054$	-0.035	$+0.684$	-0.176	...	$+0.140$
24	$+1.726$	-0.007	$+0.755$	-0.200	$\frac{1}{2}$	$+0.163$
25	$+1.449$	-0.004	$+0.760$	-0.403	...	-0.050
26	$+1.956$	$+0.083$	$+0.811$	-0.509	...	-0.115
27	$+0.874$	$+0.226$	$+0.384$	-0.123	$\frac{1}{2}$	$+0.051$
28	$+1.124$	$+0.226$	$+0.384$	-0.283	...	-0.098
29	$+0.874$	$+0.245$	$+0.292$	-0.102	$\frac{1}{2}$	$+0.035$
30	$+0.652$	$+0.248$	$+0.278$	$+0.149$	$\frac{1}{2}$	$+0.270$
31	$+0.567$	$+0.292$	$+0.055$	-0.074	...	-0.046
32	$+0.652$	$+0.311$	-0.044	-0.011	...	-0.019
33	$+0.616$	$+0.319$	-0.087	$+0.298$	$\frac{1}{2}$	$+0.271$
34	$+0.616$	$+0.377$	-0.374	$+0.299$	$\frac{1}{2}$	$+0.156$
35	$+0.485$	$+0.404$	-0.495	$+0.462$	...	$+0.264$
36	$+0.532$	$+0.415$	-0.540	-0.191	...	-0.405

Solving these equations by the method of least squares, and taking account of the weights in the second last column, we find the following normal equations :

$+29{\cdot}00\,w$	$+20{\cdot}69\,x$	$-2{\cdot}74\,y$	$-3{\cdot}73\,z$	$+0{\cdot}959=0$
$+20{\cdot}69$	$+21{\cdot}60$	$-0{\cdot}58$	$+3{\cdot}40$	$-2{\cdot}015=0$
$-\ 2{\cdot}74$	$-\ 0{\cdot}58$	$+2\ 66$	$+2{\cdot}68$	$-1\ 043=0$
$-\ 3{\cdot}73$	$+\ 3{\cdot}40$	$+2{\cdot}68$	$+9{\cdot}48$	$-3{\cdot}949=0$

from which we deduce

	Weight.
$w=-0''{\cdot}014\pm0''{\cdot}050$	3·72
$x=+0{\cdot}043\pm0{\cdot}058$	2·74
$y=-0{\cdot}016\pm0{\cdot}072$	1·79
$z=+0{\cdot}400\pm0{\cdot}055$	3·05

and for the probable error of a single observation,

$$r=\pm0''{\cdot}0956.$$

Comparing this with Sir Robert Ball's solution, namely,

	Weight.
$w=+0''{\cdot}027\pm0''{\cdot}021$	27·28
$y=-0{\cdot}094\pm0{\cdot}122$	0·8145
$z=+0{\cdot}465\pm0{\cdot}050$	4·887
$\kappa=+0{\cdot}033\pm0{\cdot}049$	4·973

and

$$r=\pm0''{\cdot}1099,$$

we see that it represents the observations better, as is shown both by the smaller value of r and by the fact that the theoretical weights of the various quantities are much more nearly equal in it than in Sir Robert Ball's solution.

Whilst engaged in this work I happened to call to mind two cases in which observers of deservedly high reputation were led to suspect the existence of a systematic error depending on the hour angle of observation.

In the Second Part of *The Dunsink Observations and Researches*, when discussing the measures of the position angle of the 9th magnitude companion to 85 *Pegasi*, Dr. Brünnow says : "In order to see whether these values exhibit any dependence on the position in which the stars were observed with regard to the vertical circle I have computed for every observation the angle $p'-\eta=N$, where η is the parallactic angle ; and I give in the following table the values of p arranged according to the values of this angle :—

* * * * * * *

As the values in this table seem to indicate a maximum when N is in the neighbourhood of 90°—that is, when the line joining the stars is in a horizontal position—I have assumed the correction which must be applied to the observed angles of position, when the angle with the vertical line is

$$90° \mp N$$

to be of the form

$$+\frac{x}{\Delta}(1-\sin N),$$

and I have introduced such a term in the equations of condition."

It is scarcely to be wondered at that, with an expression so different in form from the true one (if the systematic difference he suspected be due to unequal refrangibility), he should not have found this term add anything to the accuracy of the results.

Beyond, however, noticing in a general way that the value of p seems, from Brünnow's table, to increase with ζ quite as much as with N, I have not further pursued the subject at present, my attention having been wholly occupied with the series of measures of the parallax of *α Centauri* made by Drs. Gill and Elkin at the Cape of Good Hope in the years 1881–82–83.

In the account of these observations, which is published in the *Memoirs of the Royal Astronomical Society*, vol. xlviii., Dr. Gill remarks on page 17: "I soon obtained unquestionable evidence of the existence of considerable systematic error depending on the hour angle of observation." He therefore divides his observations into four groups, thus:

(i.) Observations made at great hour angles east,
denoted thus ⏐●⏐

(ii.) Observations made at small hour angles east,
denoted thus —●—

(iii.) Observations made at small hour angles west,
denoted thus ⏐○⏐

(iv.) Observations made at great hour angles west,
denotes thus —○—

And he remarks further, on page 23: "A glance at the diagram, at the times when nearly simultaneous observations were made east and west of the meridian will show that, as a rule, the greatest values of $\alpha-\beta+\Delta D$ occur with observations marked ⏐●⏐, and the smallest with those marked ⏐○⏐: that is, when the corresponding values of $p-q$ differ about 180°; and that the observations marked —●— and —○— occupy intermediate positions.

"It is also clear tha any discussion in which these systematic

errors are not taken into account will give much too large a value of the parallax.

"Beyond these general conclusions it is not easy to go without a more formal discussion; nor without such discussion is it easy to decide whether the systematic corrections are a function of $(p-q)$, or whether they depend entirely on the direction of measurement with respect to the line joining the observer's eyes."

To account for this systematic difference in his first and longest series of observations, Dr. Gill introduces four unknown quantities, $x_{,}$, $x_{,,}$, $x_{,,,}$, $x_{,,,,}$, corresponding to the various positions, ●, —●—, ○, and —○— respectively. Introducing also the quantities, y depending on the time, y' on the square of the time, and z equal to 1·881 π (π being the parallax), he finds the following solution :

	R R	Weight.
$x_{,}$	$= +0\cdot0178 \pm 0\ 0022$	17·2
$x_{,,}$	$= -0\ 0003 \pm 0\cdot0030$	9·5
$x_{,,,}$	$= -0\cdot0214 \pm 0\cdot0018$	24·7
$x_{,,,,}$	$= +0\cdot0093 \pm 0\ 0029$	9 7
y	$= -0\cdot0026 \pm 0\ 0037$	6·2
y'	$= -0\cdot0002 \pm 0\ 0032$	8·2
z	$= +0\cdot1092 \pm 0\ 0019$	22·3

This solution makes the probable error of a single observation of weight unity equal to

$$r = \pm 0\cdot00918 = \pm 0''\cdot1181,$$

and the parallax

$$\pi = 0''\cdot747 \pm 0''\cdot0133,$$

which value of the parallax Dr. Gill takes as the definitive result to be obtained from this series of observations.

The systematic differences for which Dr. Gill found it necessary to correct in this empirical manner seem to me to be exactly such as we should expect to arise from a small difference of refrangibility in the light of the stars under consideration. I have accordingly examined this series of measures, and the three which follow it in the same memoir, with a view to establishing the existence of such a difference.

In each of the four series of observations of this star the method of observation was the same. The distance of α_2 *Centauri* was measured with the heliometer from two comparison stars situated nearly symmetrically at opposite sides of it, in each series a different pair of comparison stars being employed.

Denoting, then, by

S_0, the mean sum of the distances (in the first series $= 536^{R}\cdot 0510$);

S, any particular sum of the distances;

D_0, the mean difference of the distances ($= 60^{R}\cdot 000$);

D, any particular observed difference of the distances;

ΔD, the correction to be applied to D to reduce to normal scale value;

Dr. Gill takes

$$\Delta D = (S_0 - S) \times \frac{D}{S},$$

or practically

$$\Delta D = \frac{D_0}{S_0}(S_0 - S) = 0\cdot 112\,(S_0 - S).$$

Now, if α be the corrected distance as found by Dr. Gill from the first comparison star, β the corrected distance from the second, and k_1, k_2, k the values of the constant of refraction, which are applicable to the two comparison stars and to α *Centauri* respectively, then the true distances are

$$\alpha' = \alpha - (k_1 - k)\tan\zeta\cos(p_1 - q),$$

and

$$\beta' = \beta - (k_2 - k)\tan\zeta\cos(p_2 - q).$$

As the position angles of the comparison stars in each case differ very nearly by 180°, we may without sensible error put

$$p_1 = 180^\circ + p_2;$$

and we obtain

$$\alpha' = \alpha - (k_1 - k)\tan\zeta\cos(p - q),$$
$$\beta' = \beta + (k_2 - k)\tan\zeta\cos(p - q);$$
$$\therefore\ S' = S - (k_1 - k_2)\tan\zeta\cos(p - q);$$

and

$$D' = D - (k_1 + k_2 - 2k)\tan\zeta\cos(p - q);$$

and since

$$\Delta D' = (S_0 - S') \times \frac{D'}{S'},$$

it is easy to show that, to the same degree of approximation as before,

$$\alpha' - \beta' + \Delta D' = \alpha - \beta + \Delta D - \frac{S_0}{S}\left\{(k_1 + k_2 - 2k) - (k_1 - k_2)\frac{D_0}{S_0}\right\}\tan\zeta\cos(p - q),$$

or simply

$$\alpha' - \beta' + \Delta D' = \alpha - \beta + \Delta D - x\tan\zeta\cos(p - q).$$

Hence if w is a correction to the assumed difference of the distances D_0; y the effect of proper motion on D_0; and z equal to

1·881 π we find (*cf.* Gill and Elkin's memoir) from each observation an equation of the form

$$w + \tan\zeta\cos(p-q)\,.\,x + ty + \mathrm{R}\,.\,\cos(\odot - 347^{\circ}\cdot 3)\,z = \mathrm{D} - \mathrm{D}_0.$$

We are thus led to a series of equations of condition for which the weights apportioned by Dr. Gill have been retained. Equations 8, 15, 16, 28, 29, 41, 48, 65, 66, 77, and 89 have been omitted from the solution for reasons given in Dr. Gill's memoir. Equations 16, 28, 29, 48, and 89 might indeed have been included in this investigation, as the reason which led Dr. Gill to reject them—namely, uncertainty as to the position of the observer's head—does not apply in this case, and the smallness of the residuals of all but the last of them shows that the results would not have been sensibly altered if they had been included. I have, however, rejected these equations in what follows so as to make my result more strictly comparable with Dr. Gill's, depending as it does on the very same material.

I have taken the values of $\tan\zeta\cos(p-q)$ to only two decimal places because each observation extended over a considerable time, and consequently the exact sidereal time to which it corresponds does not admit of being stated with any very high degree of precision, and it would have added very considerably to the labour of computing without adding anything to the real accuracy of the correction if I had attempted to include the third decimal.

From these equations (omitted here for economy of space) * we obtain the following normals :

$$\begin{aligned}
&+86\cdot50w - 10\cdot40x + 31\cdot35y + 9\cdot98z - 0\cdot75 = 0\\
&-10\cdot40 + 58\cdot26 + 0\cdot09 + 32\cdot87 - 4\cdot19 = 0\\
&+31\cdot35 + 0\cdot09 + 36\cdot56 + 14\cdot95 - 1\cdot42 = 0\\
&+9\cdot98 + 32\cdot87 + 14\cdot95 + 48\cdot42 - 5\cdot65 = 0
\end{aligned}$$

Solving these we find

	R	R	Weight.
$w =$	$-0\cdot0011$	$\pm 0\cdot0017$	57·5
$x =$	$+0\cdot0074$	$\pm 0\cdot0023$	31·2
$y =$	$-0\cdot0068$	$\pm 0\cdot0028$	21·9
$z =$	$+0\cdot1140$	$\pm 0\cdot0027$	23·6

whence

$$\pi = 0''\cdot780 \pm 0''\cdot018.$$

The probable error of a single observation comes out somewhat greater than that found by Dr. Gill, viz.—

$$r = \pm 0\cdot01311 = \pm 0''\cdot1686;$$

but this is hardly to be wondered at considering that there are

* The factors of x and the residuals will be found on p. 144. The other terms will be found in Dr. Gill's memoir.

in his solution no less than seven unknown quantities amongst which the errors are distributed. We see again, however, that, as in the case of 61 *Cygni*, the introduction of the quantity x tends to equalise the weights with which the various quantities are deduced, and in this case, while the probable error of z is only increased by less than one-half its amount, that of y is diminished in about the same proportion, and that of w is smaller than the probable error of any one of the four corresponding quantities which Dr. Gill employs. The high theoretical weight, too, attached to x, which is greater than that of either y or z, would seem to show that it represents a real systematic error affecting the measures.

With regard to the difference in refrangibility to which this value of x would correspond, since

$$\overset{\mathrm{R}}{1} = 12''\cdot865,$$

we find that

$$x = 0''\cdot0952,$$

or about double that found above in the case of 61 *Cygni*, and a trifle greater than that found for β *Cygni*.

Second Series.—Gill.—This second series of measures is in many respects much less satisfactory than the former. It was undertaken as a check on the first and principal series, employing a different pair of comparison stars, and contains only 46 observations in all, which are mostly confined to the epochs of the maxima and minima of parallax. "But," Dr. Gill remarks, "as the observations near the maximum of parallax were necessarily made east of the meridian, and those near the minimum of parallax west of it, some connecting link between observations made in these two conditions was desirable in order to determine whether the deduced parallax is affected by possible systematic error depending on the hour angle of observation.

"Accordingly observations were made in May and June 1883—in the evening east of the meridian, and in the morning west of it—at hour angles similar with those at which the observations near the maximum and minimum of parallax were made."

In this series Dr. Gill introduces only two terms, x_{E} and x_{W}, corresponding to observations made east and west of the meridian respectively, but still retains the quantity y' depending on the square of the time. He has evidently been at great pains to find a satisfactory solution, and obtains several, of which none are quite unexceptionable.

What appears the best of these is obtained by making $x_{\mathrm{E}} = x_{\mathrm{W}}$, and rejecting (by Pierce's Criterion) equations 1 and 31; but this, as Dr. Gill points out, gives such a large value of y' as cannot be reconciled with the results of meridian observations, nor with an orbit representing the heliometer observations of α *Centauri* as a double star.

The solution gives

	R	R	Weight
$x^R = x_W =$	$+0''.0047$	$\pm 0''.0021$	17·27
$y =$	$-0''.0217$	$\pm 0''.0053$	2·66
$y' =$	$+0''.0165$	$\pm 0''.0041$	4·37
$z =$	$+0''.1144$	$\pm 0''.0018$	23·37

whence

$$\pi = 0''.768 \pm 0''.012 ;$$

also

$$r^R = \pm 0''.00865 = \pm 0''.111.$$

Treating this series in the same way as the last, and including all the observations except those which Dr. Gill rejected for *a priori* reasons—namely, Nos. 5, 8, 13, 18, and 22—and giving with him half weight to Nos. 32 and 35, we find the resulting normal equations :—

$+40''.00\,w$	$+\ 0''.03\,x$	$+27''.37\,y$	$-\ 9''.29\,z$	$+0''.866 = 0$
$+\ 0''.03$	$+30''.91$	$-\ 2''.80$	$-23''.65$	$+2''.590 = 0$
$+27''.37$	$-\ 2''.80$	$+37''.31$	$-\ 6''.66$	$+0''.768 = 0$
$-\ 9''.29$	$-23''.65$	$-\ 6''.66$	$+30''.12$	$-3''.224 = 0$

From which we obtain

	R	R	Weight
$w =$	$+0''.0082$	$\pm 0''.0028$	19·01
$x =$	$-0''.0055$	$\pm 0''.0038$	10·41
$y =$	$-0''.0086$	$\pm 0''.0029$	17·71
$z =$	$+0''.1034$	$\pm 0''.0040$	9·55

Hence

$$\pi = 0''.694 \pm 0''.028 ;$$

also

$$r^R = \pm 0''.0121 = \pm 0''.1557.$$

The residuals obtained from this solution * are very similar to those found by Dr. Gill, and though the value of r is slightly larger than he finds in his final solution, this has the advantage of being free from an inadmissible value of y', and also, as in the previous cases, brings the weights of the various quantities much closer together, that of x exceeding the corresponding quantity for z.

With regard to the negative sign found for x, it should be remarked that in these observations a wire gauze screen was used to reduce α_2 *Centauri* to about the same magnitude as the two comparison stars employed at the time, and that whereas in the first series of each observer, α_2 *Centauri* thus reduced seemed slightly brighter than the mean of the comparison stars, in this case it was otherwise, the principal star appearing slightly fainter than the mean of the two. On the other hand, in Dr. Elkin's

* See p. 144.

second series the screen had the effect of reducing α_2 *Centauri* to about the brightness of a star of magnitude $8\frac{1}{4}$, while the comparison stars were each of the eighth magnitude, and in that case I have found a positive value of x. But it is extremely unlikely that such minute differences of brightness could have any sensible effect on the measures. It will be seen, however, from the expression for x on p. 136 that this quantity is not necessarily positive ; for if the light of the two comparison stars differs in refrangibility considerably more than their mean does from that of α_2 *Centauri*, or if

$$(k_1 - k_2)\frac{D_0}{S_0}$$

is greater than

$$(k_1 + k_2 - 2k),$$

we should have a negative value for x.

It would be interesting to know whether any difference in the colour of these comparison stars can be detected by the eye, or whether any peculiarity is exhibited in the spectrum of either.

We have next to consider the measures of Dr. Elkin, made at the same time, with the same instrument and following the same method

First Series.—Elkin.—This consists of ninety-two observations in which a third pair of comparison stars was employed, whose position with regard to α *Centauri* as well as all information necessary for a complete examination of the results will be found in the original memoir.

This series gives very different values of the parallax (ranging from $0''{\cdot}650$ to $0''{\cdot}815$) according to the method of solution.

In one of these Dr. Elkin is driven to the use of five empirical corrections x_W, x_{MW}, x_M, x_{EM}, x_E depending on the hour angle of observation, while in another he solves for eight unknowns, which, as might have been expected, has the effect of reducing the probable error a good deal.

Equations of condition, formed just as in the previous cases, lead to the following normal equations, in which $z = 1{\cdot}580\,\pi$:

$+87{\cdot}00\,w$	$+\ 5{\cdot}91\,x$	$-15{\cdot}64\,y$	$+17{\cdot}59\,z$	$+0{\cdot}145 = 0$
$+\ 5{\cdot}91$	$+27{\cdot}82$	$+\ 0{\cdot}65$	$-24{\cdot}02$	$+1{\cdot}762 = 0$
$-15{\cdot}64$	$+\ 0{\cdot}65$	$+16{\cdot}19$	$+\ 0{\cdot}39$	$-0{\cdot}397 = 0$
$+17{\cdot}59$	$-24{\cdot}02$	$+\ 0{\cdot}39$	$+52{\cdot}15$	$-3\,872 = 0$

whence we obtain

	R	R	Weight
$w =$	$-0{\cdot}0208$	$\pm 0{\cdot}0024$	52·56
$x =$	$+0{\cdot}0186$	$\pm 0{\cdot}0048$	13·37
$y =$	$+0{\cdot}0015$	$\pm 0{\cdot}0050$	12·24
$z =$	$+0{\cdot}0898$	$\pm 0{\cdot}0036$	23·42

$\pi = 0''{\cdot}732 \pm 0''{\cdot}032$

and for the probable error of a single observation,

$$r = \pm 0^{R}0175 = \pm 0''.225.$$

A comparison of the residuals* found by the substitution of these values in the equations of condition with those obtained by Dr. Elkin in his first solution, to which he attaches no weight in deducing his final result, shows that in one respect there is apparently little improvement, namely, in the decided change of sign of the residuals which occurs between the observations 53 and 54 at the point where the observations change from one side of the meridian to the other. On the other hand, there is not the same systematic dependence on hour angle towards the end of the series (where observations, both east and west of the meridian, were obtained) which Dr. Elkin's solution very clearly exhibits.

It would therefore seem that, whatever this systematic error may be due to, when the correction for the dispersion is introduced its effect seems to be confined to bringing about the change of sign in the residuals which takes place about the end of October at the fifty-third equation of condition. Now in the observations taken about this date, the Sun and *α Centauri* were, comparatively speaking, close to one another—almost on the same hour circle—and the star was about 20° above the horizon, while the Sun was only 10° or 12° below it. In fact, these observations were made at the greatest zenith distances of any in the whole four series. Under these circumstances they must have been made in a bright twilight sky, and the contrast made by the light of the stars with the illuminated field must have been very different from what it was at other times, when the stars appeared on a background illuminated only by artificial light.

Under these circumstances it would probably reduce the residuals considerably if we introduced a special correction x_1 to be applied to all observations made in a twilight sky—a step which would still leave the number of our unknown quantities three less than those employed by Dr. Elkin—but as my object at present is, not to improve on the value of the parallax deduced by Dr. Elkin, but to examine the effect which atmospheric dispersion may have on such measures, I have not done so.

I merely remark that the value of the parallax found in a direct way, without any empirical corrections, agrees very closely with the result which Dr. Elkin is finally led to adopt, and is almost exactly equal to the mean of the values found in the same manner from Dr. Gill's two series of observations.

Second Series.—Elkin.—Dr. Elkin's second series of measures of *α Centauri* is similar to that of Dr. Gill, consisting of observations made about the epochs of maximum and minimum parallax with a group made east and west of the meridian to free this series from systematic errors, such as had been found to exist in the others.

* See p. 145.

These observations furnish fifty equations of condition, of which all but one (No. 24) are employed in the solution, and this one is rejected on account of the fact that the measures were made immediately after the opening of the dome. The observations show a very decided difference depending on the side of the meridian on which they were made. Dr. Elkin is therefore led to introduce the two quantities x_E and x_W, which are applicable to observations made on the eastern and western sides of the meridian respectively, and obtains the following solution when the observations are all given equal weights :

$$\begin{aligned} x_E &= -0''.0231 \pm 0''.0048 \\ x_W &= +0''.0201 \pm 0''.0048 \\ y &= +0''.0261 \pm 0''.0037 \\ z &= +0''.1033 \pm 0''.0047 \end{aligned}$$

in which

$$z = 1.920\pi,$$

whence he finds

$$\pi = 0''.672 \pm 0''.031;$$

also

$$r = \pm 0''.207.$$

This result he afterwards modifies slightly by assigning various weights to the observations according to the character of the images at the time, and finally deduces

$$\pi = 0''.676 \pm 0''.027$$

as the definitive result of the series.

If we treat these observations as we did the three previous series, we obtain fifty equations of condition ; and considering all the observations, with the exception of No. 24, as of equal weight we obtain the normal equations

$+49.00\,w$	$+\ 2.73\,x$	$+24.70\,y$	$+\ 2.94\,z$	$-0.895 = 0$
$+\ 2.73$	$+60.95$	$-\ 1.03$	-36.54	$+2.781 = 0$
$+24.70$	$-\ 1.03$	$+32.60$	$+\ 7.15$	$-1.512 = 0$
$+\ 2.94$	-36.54	$+\ 7.15$	$+33.19$	$-2.931 = 0$

Hence we find

	Weight.
$w = -0''.0018 \pm 0''.0031$	30.07
$x = +0''.0132 \pm 0''.0039$	19.20
$y = +0''.0269 \pm 0''.0040$	18.42
$z = +0''.0972 \pm 0''.0054$	9.97
$\pi = +0''.651 \pm 0''.036$	

and

$$r = \pm 0''.220$$

The close agreement which a comparison of the residuals* afforded by this solution with those found by Dr. Elkin exhibits would seem to show unquestionably that the systematic error, which Dr. Elkin corrects for by the empirical quantities x_R and x_W, is due to a difference in the mean refrangibility of the light of the stars such as I have supposed to exist.

It appears to me that the result of all these observations—my own observations of *β Cygni* and of *γ Andromedæ*, those by Sir Robert Ball of 61 *Cygni*, and the splendid series of heliometer measures of *α Centauri* by Drs. Gill and Elkin all point in the same direction, and show that small differences in the mean refrangibility of the light of stars may make themselves felt in precise measurements of their position. And whatever value may be assigned to the particular solutions which I have found for the four series of observations made at the Cape of Good Hope, and whether it be thought that the correction I have introduced accounts fully for the systematic error depending on hour angle which runs through them all, and that the still outstanding quantities should be attributed to the accidental errors inseparable from observations of such delicacy and difficulty (as I believe to be the case in both of Dr. Gill's and in Dr. Elkin's second series), or that the observations are further affected by a systematic error, possibly of a subjective character (as would seem to be the case in Dr. Elkin's first series), I think I have shown at least that in parallax measures a term ought to be introduced into the equations of condition of the form

$$\lambda\beta \tan \zeta \cos (p-q)$$

where results of the highest precision are aimed at.

In conclusion I may remark that although the introduction of such a term has somewhat altered the individual results from those given in the original memoir, yet its effect on the final value of the parallax of *α Centauri* is less than the one-hundredth part of a second. For if we take the mean of the four different values obtained by me with the weights attributed to the corresponding quantities by Drs. Gill and Elkin, we find

$$\pi = 0''.743$$

as compared with the value

$$\pi = 0''.752$$

obtained by those distinguished astronomers.

* See p. 145.

First Series—Gill.

No.	tan ζ cos (p−q).	Res. R	No.	tan ζ cos (p−q).	Res. R
1	+0·04	+0·004	56	−1·43	−0·018
2	+0·18	+ ·017	56a	+0·72	− ·027
3	−0·49	+ ·028	57	−1·38	− ·040
4	−0·38	+ ·013	58	−0·98	·000
5	−0·04	+ ·019	59	+0·67	+ ·005
6	−0·59	+ ·019	60	+0·72	− ·010
7	−0·04	+ ·008	61	+0·73	− ·028
9	−0·39	+ ·016	62	−0·28	+ ·034
10	−0·19	+ ·007	63	+0·72	− ·013
11	−0·63	+ ·003	64	+0·72	− ·026
12	−0·84	+ ·001	67	−0·88	+ ·005
13	−0·56	− ·007	68	−0·59	+ ·019
14	−0·75	+ ·028	69	−1·26	− ·017
17	−1·20	− ·036	70	−0·77	− ·005
18	−2·39	− ·040	71	−0·82	+ ·012
19	−1·27	− ·008	72	−1·58	− ·015
20	−1·62	+ ·015	73	−0·32	+ ·009
21	−1·83	− ·028	74	−0·20	+ ·047
22	+0·49	+ ·012	75	−1·82	− ·055
23	+0·64	+ ·005	76	−0·16	+ ·008
24	+0·66	+ ·009	78	−0·57	+ ·007
25	+0·69	− ·006	79	−0·51	− ·007
26	+0·71	+ ·004	80	−0·85	+ ·010
27	+0·67	+ ·003	81	−0·40	+ ·032
30	+0·65	− ·017	82	−0·60	+ ·004
31	+0·60	+ ·015	83	−0·67	+ ·021
32	+0·68	− ·017	84	−0·71	+ ·005
33	+0·65	+ ·001	85	−1·08	− ·018
34	+0·70	+ ·003	86	−1·55	− ·005
35	+0·70	− ·011	87	−1·37	− ·067
36	+0·57	+ ·016	88	+0·72	− ·007
37	+0·67	− ·013	90	+0·68	+ ·001
38	+0·70	·000	91	+0·72	− ·021
39	+0·71	− ·011	92	−0·31	+ ·030
40	+0·69	+ ·010	93	−0·28	+ ·049
42	+0·68	− ·005	94	−0·39	+ ·013
43	+0·66	+ ·011	95	+0·71	+ ·008
44	0·00	+ ·011	96	−0·23	+ ·025
45	+0·67	− ·033	97	+0·70	+ ·055
46	+0·67	− ·019	98	+0·72	− ·028
47	+0·64	− ·010	99	−0·96	+ ·025
49	−0·44	+ ·002	100	−0·51	+ ·016
50	+0·72	− ·003	101	+0·67	− ·013
51	−0·56	+ ·019	102	−0·38	+ ·039
52	+0·71	− ·005	103	+0·68	− ·013
53	−0·58	+ ·017	104	+0·72	− ·032
54	+0·69	+ ·001	105	−0·18	+ ·006
55	+0·67	− ·009			

Second Series—Gill.

No.	tan ζ cos (p−q).	Res. R
1	+0·54	−0·050
2	+0·71	− ·011
3	+0·65	+ ·002
4	+0·55	+ ·029
6	+0·69	− ·025
7	+0·63	+ ·017
9	−0·94	− ·002
10	−0·85	·000
11	−0·86	− ·019
12	−0·93	+ ·022
14	−0·96	− ·004
15	−0·70	− ·005
16	−0·63	− ·002
17	−0·76	− ·002
19	+0·97	+ ·021
20	+1·04	+ ·019
21	+0·92	+ ·019
23	+0·96	+ ·006
24	+0·88	− ·004
25	+0·98	+ ·006
26	+0·89	+ ·012
27	+1·00	+ ·013
28	−1·29	+ ·001
29	−1·37	− ·025
30	−0·94	− ·013
31	−1·00	+ ·054
32	−0·91	+ ·007
33	−0·82	+ ·014
34	+0·83	− ·006
35	+0·71	− ·015
36	−0·90	− ·004
37	+0·84	− ·038
38	−0·84	+ ·002
39	−0·82	− ·003
40	+1·04	− ·023
41	−0·74	+ ·008
42	+0·98	+ ·010
43	−0·70	− ·004
44	−0·67	− ·012
45	+0·88	+ ·006
46	+0·97	− ·008

First Series—Elkin.

No.	$\tan\zeta\cos(p-q)$.	Res. R
1	+0·01	+0·012
2	−0·42	+ ·018
3	−0·11	− ·022
4	−0·25	− ·013
6	−0·39	+ ·001
7	−0·27	− ·014
8	−0·36	− ·022
9	−0·38	+ ·015
10	−0·26	+ ·011
11	−0·27	− ·028
12	−0·35	+ ·009
13	−0·30	− ·014
14	−0·40	− ·044
15	−0·39	− ·040
16	−0·47	+ ·014
17	−0·50	− ·010
18	−0·30	+ ·010
19	−0·46	+ ·021
22	−0·32	+ ·054
23	−0·48	+ ·039
24	−0·39	+ ·014
25	−0·40	+ ·054
26	−0·14	+ ·020
27	−0·38	+ ·028
28	−0·32	+ ·010
29	−0·35	− ·033
30	−0·32	+ ·006
31	−0·01	− ·023
32	+0·11	− ·013
33	−0·20	− ·018
34	+0·22	− ·011
35	−0·01	− ·032
36	+0·14	− ·001
37	+0·16	− ·020
38	+0·12	− ·027
39	+0·41	− ·007
40	+0·62	+ ·021
41	+0·22	·000
43	+0·71	− ·057
44	+0·38	·000
45	+0·47	− ·032
46	+0·97	+ ·023
47	+0·45	− ·034
48	+1·42	− ·015
49	+0·71	−0·037
50	+1·01	− ·004
51	+1·35	− ·028
52	+1·98	− ·013
53	+2·12	− ·002
54	+0·99	+ ·045
55	+0·89	+ ·018
56	+0·48	+ ·062
57	+0·46	+ ·048
58	+0·28	+ ·038
59	+0·81	+ ·034
60	−0·08	+ ·006
61	+0·71	+ ·016
62	+0·40	+ ·010
63	+0·20	+ ·030
64	+0·75	+ ·036
65	+0·32	+ ·029
66	+0·41	+ ·026
67	−0·33	+ ·013
68	+0·19	+ ·014
69	−0·43	+ ·029
70	+0·27	+ ·001
71	−0·38	− ·013
72	−0·48	+ ·022
73	−0·44	·000
74	−0·04	− ·036
75	−0·39	− ·006
76	−0·50	+ ·029
77	−0·51	+ ·010
78	−0·46	+ ·002
79	−0·51	+ ·004
80	+0·21	− ·056
81	−0·10	− ·017
82	+0·57	− ·002
83	−0·11	− ·023
84	−0·25	− ·029
85	−0·43	− ·004
86	−0·44	− ·004
87	−0·43	− ·007
88	−0·02	− ·015
89	−0·26	− ·032
90	−0·26	+ ·003
91	+0·44	+ ·003
92	−0·14	− ·030

Second Series—Elkin.

No.	$\tan\zeta\cos(p-q)$.	Res. R
1	+1·02	+0·005
2	+0·36	− ·023
3	+0·64	− ·005
4	+1·87	+ ·006
5	+0·93	+ ·010
6	+0·77	− ·016
7	+1·37	+ ·037
8	+1·55	− ·002
9	+1·22	− ·004
10	−0·91	− ·020
11	−1·67	− ·010
12	−0·99	+ ·007
13	−0·90	+ ·019
14	−1·42	− ·022
15	−1·55	− ·032
16	−0·48	+ ·013
17	−0·71	+ ·012
18	−0·90	+ ·012
19	−0·97	+ ·031
20	−0·49	+ ·018
21	−0·58	− ·007
22	−1·62	+ ·004
23	−1·24	− ·028
25	−1·17	+ ·002
26	+1·06	− ·028
27	+1·65	+ ·005
28	+1·43	− ·023
29	+1·62	+ ·023
30	+1·40	− ·020
31	+1·34	− ·007
32	+1·43	+ ·011
33	+1·58	+ ·057
34	−1·14	+ ·086
35	+0·72	− ·021
36	+0·73	− ·012
37	−0·72	+ ·007
38	+0·81	+ ·010
39	−0·76	− ·015
40	−0·70	+ ·027
41	+0·90	− ·029
42	+0·92	+ ·008
43	+0·75	+ ·013
44	−1·08	+ ·020
45	+0·80	− ·058
46	−1·15	+ ·023
47	−0·72	− ·003
48	+0·88	− ·022
49	−1·05	− ·028
50	−1·04	− ·013

Note on Professor Newcomb's Note in the "Monthly Notices" for 1894 November. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

It is evident that Professor Newcomb is either unable or unwilling to seriously discuss the fundamental question which I have raised with respect to the accuracy of our determinations from observation of the variable, t, in terms of which our theoretical results are, or can be made, exact.

And it is useless to attempt to continue a discussion without coming to close quarters on the point at issue.

But it is not desirable that my views should be misrepresented; and it is a misrepresentation of my views for Professor Newcomb to assert that "Mr. Stone maintains that this result" (i.e. the numerical difference obtained by Professor Newcomb) "is due to my failure to apply a certain correction to the numbers of Le Verrier's Tables, which correction is not a function of anything contained in the tables, or of the epoch of any natural event, but of the date when a certain office, three thousand miles away, began to use the tables in computing the solar ephemeris." Such a statement has certainly never been made by me.

The expression for the geocentric longitude of the Sun as a function of 't,' is one thing; the expression for the right ascension of a meridian as a function of 't,' is another thing.

What I have maintained, maintain, and assert that I have proved, is as follows:—That if astronomers use for years, in the determinations of the local sidereal times, a "unit day" which is the $\frac{N}{2\pi}$th part of a mean tropical year, and turn their theoretical expressions into "time" at the rate of 2π to 86,400 mean sidereal seconds; but, for any reasons whatever, at some definite epoch introduce a change and use a "unit day" which is the $\frac{N'}{2\pi}$th part of a mean tropical year: then, simultaneously with the change of units, the mean angular motion, Ω, of the meridians in right ascension must be changed to Ω', so that

$$\Omega : \Omega' = N : N';$$

but in this case we have

$$\Omega - \Omega' = (N - N')\left(1 + \frac{2\pi}{N_0}\right) = N - N' + \frac{2\pi}{N_0}(N - N'),$$

where N_0 will be a definite angle, which, in practice, will not differ much from N or N', but cannot be equal to both N and N'. This result is generally true, and, therefore, true when the N is that of Carlini's, and the N' that of Le Verrier's, Solar Tables.

Now, although Professor Newcomb asserts that the corrections which I introduce are not functions of any natural event, it is a

simple matter of fact that he recognises that changes in Ω and Ω' result from changes in N and N′, and he carefully computes the effects of these changes in $\Omega - \Omega'$, and allows for their effects in his work so far as the term $N - N'$ is concerned, but he overlooks and, therefore, neglects the far more important effects which result from the existence of the term

$$\frac{2\pi}{\bar{N}_0}(N - N').$$

The differences between the numerical results which Professor Newcomb obtains for the local sidereal times at the commencement of each "unit day" and those which I obtain are simply due to the fact that I allow for the effects of the term

$$\frac{2\pi}{\bar{N}_0}(N - N')$$

and Professor Newcomb neglects them.

If, therefore, Professor Newcomb can prove that no such term as

$$\frac{2\pi}{\bar{N}_0}(N - N')$$

exists in the difference $\Omega - \Omega'$ under the conditions stated, then his results are right and mine are wrong; but, on the other hand, if the existence of this term is necessary to preserve continuity in our measures of time, then Professor Newcomb's results are wrong and mine are right.

The real question at issue is whether the tabular geocentric places, found as at present, and expressed as a function of t, can be correctly referred to the meridian of an observer without taking account of both the terms

$$N - N' + \frac{2\pi}{\bar{N}_0}(N - N')$$

in the expression for $\Omega - \Omega'$.

Professor Newcomb apparently considers that it is only necessary, when different fractional parts of a mean tropical year are adopted as the "unit day," to take account of the term $N - N'$; and the result is that Hansen's Lunar Tables, which, when thus compared with observation, gave, comparatively speaking, small residuals from 1750–1863, ceased to represent the observations in 1864, when the data of Carlini's Solar Tables were generally replaced by those of Le Verrier, to such an extent that, although the mean annual residual in 1863 was $1''{\cdot}54$, there has been no negative mean annual residual since that year, and the residual for 1892 amounted to $+19''{\cdot}69$, and is now over $+20'$. But when allowance is made, as I maintain must be the case to preserve the continuity of our measures of time, for the term

$$\frac{2\pi}{\bar{N}_0}(N - N')$$

the same tables represent the observations before and after 1864 with equal accuracy.

These are the facts with which observation furnishes us. I leave my readers to draw their own inferences.

See *Monthly Notices* 1894 December.

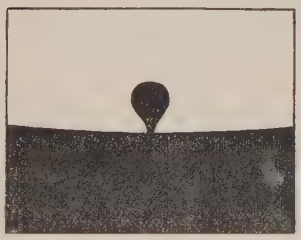
The Transit of Mercury, 1804 *November* 10, *observed in New South Wales.* By H. C. Russell, B.A., F.R.S.

The morning was fine and clear, except a slight haziness. Unfortunately, the Sun was so situated that, viewed from the large equatorial, it was behind the Time-ball Tower. I was therefore obliged to use a very fine 6-inch equatorial by Sir Howard Grubb, which occupies the north dome. This telescope defines admirably, and was for the occasion reduced by a diaphragm to 3 inches. A reflecting prism was used to reduce the light still more, and a power of 120. When the Sun was clear of lower mists, I began to observe the planet carefully. It was remarkably black compared with the Sun-spots, quite round, and fairly well defined. During the whole time I saw no white spot on the planet, or anything to mar its blackness, and there was no surrounding ring or fringe of light. Examined closely, it was seen that at short intervals definition became bad, the apparent vibration producing an ill-defined edge. The rays of the Sun were powerful, and its heating effect no doubt gave rise to currents of unequal temperature, and as these passed before the telescope the planet's limb seemed to be rippling, as if waves were passing over it. As the planet approached the Sun's limb the narrow space between seemed to throw these conditions into prominence, and it became evident, when the planet got within one-third of its diameter (estimated) of the Sun's limb, that the contacts were not to be observed under favourable conditions. A moment of bad definition came on, in which the ripples seemed to form dents in the limbs of planet and Sun from 1′ to 2″ wide, and suddenly a shady ligament joined the limbs of planet and Sun. It was darker near the planet than the Sun's limb, and seemed to be made up of soft shaded lines from limb to limb, making up a band about one-quarter of the planet's diameter wide. This lasted two or perhaps three seconds, and then disappeared, the definition having suddenly improved. The time at which the ligament formed was November 10, $19^h\ 16^m\ 1^s{\cdot}5$. The greater darkness of the ligament near *Mercury* would result from the planet being darker than the sky, and its vibrations would obviously make a darker shading than that caused by the overlapping in vibrations of the darkness outside the Sun's limb. The space between the planet and Sun's limb now became quite clear and free from dark shading, until $19^h\ 16^m\ 18^s{\cdot}5$, when

suddenly a wave of bad definition formed the ligament again ; but the limbs were quite evidently not tangential, and did not seem to me to be so until $19^h\ 16^m\ 29^s{\cdot}55$, when I recorded "*Contact of limbs.* Internal contact complete." I then looked carefully to see if the planet's limb could be seen outside the Sun, but I saw no sign of this ; and at external contact the definition was rather better than it had been, and I noted $19^h\ 18^m\ 4^s{\cdot}85$ as the time of last contact.

Mr. G. D. Hirst, who has erected a private observatory about a mile and a half west of Sydney Observatory, has kindly sent me a copy of his observations made with a $3\frac{3}{4}$-inch equatorial of 5 feet focus and good defining power ; aperture reduced to $2\frac{1}{2}$ inches, and magnifying power 100. He says :

"I send herewith two drawings of the black drop seen in the transit of *Mercury* this morning, November 10. These will, I think, be interesting, on account of the black drop phenomena which interfered materially with a satisfactory record of internal



Formation of drop at $7^h\ 16^m\ 22^s{\cdot}9$ S.M.T.

Appearance of drop 6^s later.

contact. The drop was totally unlike the phenomenon seen by me at Woodford in 1874 through the finder of the photoheliograph during the transit of *Venus*. That was a fuzzy, ill-defined stalk connecting the limbs of *Venus* and the Sun This morning *Mercury* appeared to bulge out towards the Sun's limb, and the outline of this drop when formed was perfectly sharp ; and I recorded the time of the formation and apparent contact at $19^h\ 16^m\ 22^s{\cdot}93$ S.M.T. ; and the time of watch was verified immediately afterwards by the transits of *Regulus* and χ *Crucis*. External contact at egress was noted at $19^h\ 18^m\ 2^s$, but this was not very reliable. I used the small aperture for two reasons : first, because I was afraid a larger one would break the coloured glass ; and secondly, I wanted to see if a small aperture had anything to do with the formation of the drop ; and I am now strongly inclined to think it has. Definition was moderately good, at times inferior."

Sydney Observatory :
1894 *November* 11.

Mean Areas and Heliographic Latitudes of Sun-spots in the year 1892, deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. liv., p. 130, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1892, and Table II. gives the same particulars for the entire year 1892 and for the three preceding years for the sake of comparison. The areas are given in two forms. First, projected areas—that is to say, as seen and measured on the photographs—these being expressed in millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1892 the mean daily area of whole spots, and the mean heliographic latitude of the spotted area, for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results for 1889, 1890, and 1891 being added as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuance of Carrington's series ("Observations of Solar Spots made at Redhill," by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich Civil Time, reckoning from mean midnight.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas.			Corrected for Foreshortening.		
			Umbræ.	Projected Whole Spots.	Faculæ.	Umbræ.	Whole Spots.	Faculæ.
512	1892 Jan. 7·64	27	236	1430	2899	195	1224	2997
513	Feb. 3·98	24	397	2436	2954	296	1939	3088
514	Mar. 2·32	27	178	1076	3053	141	843	3143
515	Mar. 29·63	27	167	1071	3275	118	800	3264
516	Apr. 25·89	27	283	1751	3964	206	1361	3931
517	May 23·12	27	260	1786	3213	184	1318	3336
518	June 19·32	28	432	2675	3341	323	2042	3520
519	July 16·52	27	361	2181	3062	260	1640	3049
520	Aug. 12·74	27	207	1390	2790	146	1024	2889
521	Sept. 8·99	28	233	1577	3657	160	1154	2698
522	Oct. 6·27	27	167	1044	3696	121	782	3751
523	Nov. 2·56	27	222	1222	3285	155	924	3152
524	Nov. 29·87	27	177	1140	3273	123	847	3176

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas.			Corrected for Foreshortening.	
		Umbræ.	Projected Whole Spots.	Faculæ.	Umbræ.	Whole Spots.	Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
512	1892 Jan. 7·64	27	636	+21°·99	587	−19°·09	+ 2°·28	20°·60
513	Feb. 3·98	24	514	17·55	1425	26·86	−15·09	24·39
514	Mar. 2·32	27	401	21·66	442	23·01	− 1·79	22·37
515	Mar. 29·63	27	394	13·87	406	19·54	− 3·08	16·75
516	Apr. 25·89	27	530	15·00	831	17·01	− 4·55	16·23
517	May 23·12	27	657	13·12	661	19·73	− 3·35	16·43
518	June 19·32	28	1356	13·73	686	27·89	− 0·22	18·49
519	July 16·52	27	1019	12·50	621	20·72	− 0·07	15·61
520	Aug. 12·74	27	702	14·97	322	19·55	+ 4·11	16·41
521	Sept. 8·99	28	632	12·52	522	20·50	− 2·40	16·12
522	Oct. 6·27	27	348	13·31	435	22·21	− 6·42	18·26
523	Nov. 2·56	27	334	13·25	591	21·20	− 8·77	18·33
524	Nov. 29·87	27	361	+14·39	486	−17·29	− 3·78	16·05

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
1889	360	5·0	+ 7°·26	73·0	−11°·90	−10°·68	11°·61
1890	361	53·1	+22·20	46·3	−21·75	+ 1·73	21·99
1891	363	401	+20 49	169	−19·91	+ 8·52	20·31
1892	362	607	+15·09	607	−21·69	− 3·29	18·39

The principal features of the Sun-spot record for 1892 as brought out by the above tables are:

(1) The continued increase in the mean daily area of umbræ, whole spots, and faculæ. The rate of increase was indeed not so great as in 1891, but the mean values were in each case more than double those for 1891, in the case of the faculæ considerably more than double. (2) The mean daily areas for both whole spots and faculæ already exceeded those in the maximum years of the last solar cycle. (3) And this though the high latitude still occupied by the great majority of the spots would seem to indicate that the maximum had not yet been attained. (4) The predominance of the spots in the northern hemisphere has ceased, the mean daily area of spots being precisely equal for the two hemispheres. (5) Whilst the two hemispheres have shown an equality of spotted area, they have shown a curious difference in its distribution. In the northern hemisphere there has been a marked decline in the mean latitude, and the spots there have almost reached the zone of the period of maximum. In the southern hemisphere, on the contrary, the movement has been actually away from the equator. The rate of increase in the mean daily spotted area has also been very much greater for the southern hemisphere than for the northern. (6) The very remarkable increase in the area of the faculæ. The increase of 1891 over 1890 was at a lower rate for the faculæ than for the spots. This condition has been reversed for 1892, and the mean daily area for faculæ exceeds that of 1882, the maximum year of the last cycle, by considerably more than 1000 millionths.

Royal Observatory, Greenwich:
1895 *January* 8.

Observations of Occultations of Stars by the Moon, and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1894.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars by the Moon.

Day.	Phenomenon.	Telescope.	Power.	Moon's limb.	Mean Solar Time of Observation. h m s	Observer.
1894 Jan. 12	Disapp. 24 Piscium	E. Equat.	55	Dark	7 1 38·81	C. D.
20	,, *c* Geminorum	,,	200	,,	11 9 38·69	B.
Feb. 13	,, 36 Tauri	Astrographic Equat.	225	,,	12 38 24·34	H. F.
13	,, 36 Tauri	E. Equat.	200	,,	12 38 24·29	W. B.
Mar. 16 (*a*)	,, ω^2 Cancri	,,	55	,,	12 3 1·82	D.
16 (*b*)	,, ω^2 Cancri	Altaz.	100	,,	12 3 0·79	H.
23 (*a*)	Reapp. Piazzi XIII. 317	E. Equat.	100	,,	15 0 55·12	A. C.
25 (*a*)	,, 2 Scorpii	,,	100	,,	15 51 52·21	A. C.
25 (*a*)	,, 3 Scorpii	,,	100	,,	16 19 2·98	A. C.
Apr. 9	Disapp. χ^1 Tauri	Altaz.	100	,,	7 3 46·16	H.
9	,, χ^1 Tauri	E. Equat.	55	,,	7 3 44·99	A. C.
9	,, χ^1 Tauri	Astrographic Equat.	225		7 3 45·99	A. E.
10	,, Piazzi V. 136	E. Equat.	100		10 53 26·15	B.

Day.	Phenomenon.	Telescope.	Power.	Moon's limb.	Mean Solar Time of Observation.	Observer.
					h m s	
1894 Apr. 10	Disapp. Piazzi V. 136	Astrographic Equat.	225	Dark	10 53 26·23	C. D.
11	,, 49 Aurigæ	E. Equat.	100	,,	8 39 39·05	H.
11	,, 49 Aurigæ	Altaz.	100	,,	8 39 39·66	A. C
11	,, 49 Aurigæ	4-inch Detached Tel.	...	,,	8 39 39·44	A. E.
11	,, 49 Aurigæ	Astrographic Equat.	225	,,	8 39 39·44	C. D.
11	,, 49 Aurigæ	Astrographic Finder	...	,,	8 39 39·64	J.
16	Reapp. σ Leonis	Astrographic Equat.	225	Bright	9 29 50·84	A. E.
May 12	Disapp. 37 Leonis	E. Equat.	55	Dark	7 54 7·96	D.
12	,, 37 Leonis	Altaz.	100	,,	7 54 8·43	H. F.
12 (*b*)	,, 37 Leonis	Astrographic Equat.	120	,,	7 54 8·10	C. D.
30	Reapp. ζ^1 Piscium	E. Equat.	55	,,	14 40 10·14	B.
Nov. 15 (*c*)	Disapp. 136 Tauri	,,	55	Bright	7 9 8·82	C. M.
15	,, 136 Tauri	Astrographic Equat.	225	,,	7 9 11·84	C. D.
15	Reapp. 136 Tauri	E. Equat.	55	Dark	7 49 28·27	C. M.
15	,, 136 Tauri	Astrographic Equat.	120	,,	7 49 27·79	C. D.
19	,, 34 Leonis	E. Equat.	200	,,	14 47 2·88	B.

Notes.

(*a*) The time was recorded on the chronograph. (*b*) The disappearance was instantaneous. (*c*) Moon diffused; misty.

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1894 Jan. 17	II.	Ecl. R.	First seen	E. Equat.	55	8 59 0	8 58 52	H. T.
23	I.	Ecl. R.	First seen	Astrographic Equat.	225	11 37 3		H. F.
23	I.		Bisection	,,	,,	11 39 8	11 37 17	,,
23	I.		Full brightness	,,	,,	11 41 47		,,
23	I. (*a*)	Ecl. R.	First seen	E. Equat.	55	11 37 10		O. T.
23	I.		Bisection	,,	,,	11 39 20	11 37 17	,,
23	I.		Full brightness	,,	,,	11 41 5		,,
28	III.	Ecl. R.	First seen	,,	200	6 58 32	7 3 36	A. C.
28	III. (*b*)		Full brightness	,,	,,	7 3 24		,,
28	III.	Ecl. R.	First seen	Astrographic Equat.	225	6 57 43	7 3 36	C. D.
28	III.		Bisection	,,	,,	7 2 50		,,
30	I.	Occ. D.	Bisection	E. Equat.	200	10 1 45	10 4	A. C.
30	I. (*c*)		Last seen	,,	,,	10 4 21		,,
31	I.	Tr. Ing.	First contact	Astrographic Equat.	225	7 14 0		C. D.
31	I.		Bisection	,,	,,	7 16 1	7 15	,,
31	I.		Last contact	,,	,,	7 19 0		,,
Feb. 4	III.	Ecl. D.	Began to fade	E. Equat.	100	9 18 10	9 23 9	H.
4	III. (*d*)		Last seen	,,	,,	9 25 47		,,
18	II. (*e*)	Ecl. D.	Last seen	,,	,,	6 24 35	6 25 19	B.
18	II.	Ecl. R.	First seen	,,	,,	8 41 31	8 41 27	,,
18	III. (*f*)	Occ. D.	First contact	,,	,,	11 46 57	11 54	H.
18	III.		Last seen	,,	,,	11 52 41		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1894 Feb. 24	I. (*g*)	Ecl. R.	First seen	E. Equat.	100	8 18 42	8 18 47	H.
24	I.		Full brightness	,,	,,	8 20 59		,,
Mar. 2	I.	Tr. Ing.	First contact	,,	200	9 26 55		A. C.
2	I.		Bisection	,,	,,	9 28 57	9 27	,,
2	I.		Last contact	,,	,,	9 30 9		,,
3	I.	Occ. D.	Bisection	,,	100	6 46 20	6 47	H.
3	I.		Last seen	,,	,,	6 48 9		,,
4	II. (*h*)	Occ. D.	First contact	,,	,,	8 55 54		,,
4	II.		Bisection	,,	,,	8 58 43	9 3	,,
4	II.		Last seen	,,	,,	9 2 8		,,
10	I. (*i*)	Occ. D.	First contact	Astrographic Equat.	225	8 43 55	8 46	C. D.
11	I.	Sh. Ing.	First contact	,,	,,	7 8 35		,,
11	I.		Bisection	,,	,,	7 9 30	7 8	,,
11	I.		Last contact	,,	,,	7 11 34		,,
11	I.	Tr. Egr.	First contact	E. Equat.	100	8 5 10		H.
11	I.		Bisection	,,	,,	8 7 50	8 9	,,
11	I.		Last contact	,,	,,	8 11 19		,,
11	I. (*j*)	Tr. Egr.	First contact	Astrographic Equat.	225	8 4 21		C. D.
11	I.		Bisection	,,	,,	8 6 15	8 9	,,
11	I.		Last contact	,,	,,	8 9 0		,,
13	II.	Tr. Egr.	First contact	E. Equat.	55	9 16 34	9 20	D.
13	II.		Last contact	,,	,,	9 18 59		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1894 Apr. 10	I. (*k*)	Tr. Ing.	First contact	E. Equat.	200	8 23 27	8 25	B.
10	I. (*l*)		Last contact	,,	,,	8 26 0		,,
Sept. 26	I. (*m*)	Occ. R.	First seen	,,	100	13 23 36	13 23	H.
26	I.		Last contact	,,	,,	13 27 45		,,
Oct. 27	I.	Tr. Ing.	First contact	,,	200	10 15 34	10 20	A. C.
27	I.		Bisection	,,	,,	10 17 31		,,
Nov. 15	II.	Ecl. D.	Last seen	,,	55	9 36 39	9 35 21	C. M.
22	II.	Ecl. D.	Last seen	,,	200	12 11 4	12 10 34	B.
Dec. 12	I.	Tr. Ing.	First contact	28-inch Equat.	370	9 41 49		L.
12	I.		Bisection	,,	,,	9 44 49	9 47	,,
12	I.		Last contact	,,	,,	9 46 46		,,
12	I.	Tr. Ing.	First contact	Corbett Equat.	...	9 41 3		C. L.
12	I.		Bisection	,,	...	9 44 46	9 47	,,
12	I.		Last contact	,,	...	9 47 4		,,

Notes.

(*a*) Not good observation. (*b*) Probably early. (*c*) Not a good observation; cloudy.
(*d*) This time may be a few seconds early. The planet was dimmed just at this time, perhaps by passing cloud. The satellite had certainly disappeared 25 seconds later. (*e*) Not a good observation. Sky hazy and J. II. close to limb.
(*f*) Not a good observation. Jupiter very low. (*g*) A good observation. (*h*) Considered a good observation.
(*i*) Cloudy. Doubtful. (*j*) Very windy. (*k*) Very rough. (*l*) Rough.
(*m*) Not a good observation. The time should perhaps be earlier.

The initials H. T., D., L., H., A. C., B., A. E., H. F., C. M., C. D., W. B., O. T., J., and C. L. are those of Mr. Turner, Mr. Dyson, Mr. Lewis, Mr. Hollis, Mr. Crommelin, Mr. Bryant, Miss Everett, Mr. Furner, Mr. Martin, Mr. Davidson, Mr. Bowyer, Mr. Tuck, Mr. Johns, and Mr. Lacey respectively.

Observations of Encke's Comet made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the East, or Sheepshanks, Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to one another, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time.					Observer.	✐−✱ RA.	Corr. for Refraction.	Corr. for Parallax.	✐−✱ N.P.D.	Corr. for Refraction.	Corr. for Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. ✱
1894.	d	h	m	s		m s	s	s	′ ″	″	″		h m s	° ′ ″	
Dec.	27	8	6	12	H.	+0 48·28	−0·02	+0·39	+4 13·4	+0·2	−7·9	6	22 15 5·34	86 20 18·6	*a*
	27	8	11	47	,,	+1 33·49	+0·02	+0·39	−2 33·8	−0·2	−7·9	4	22 15 5·79	86 20 16·4	*b*
	30	5	42	52	B.	−1 18·59	+0·01	+0·23	−8 13·2	−0·2	−7·9	3	22 14 23·56	86 42 21·5	*c*
	31	5	54	41	A. C.	+0 48·18	0·00	+0·26	−1 14·4	0·0	−8·0	3	...	...	*d*
1895.															
Jan.	3	5	30	29	B.	+2 18 63	0·00	+0·24	−0 7·5	0·0	−8·2	3	22 13 4·39	87 16 26·3	*e*
	3	5	31	46	,,	−0 30·26	0·00	+0·25	+4 47·9	+0 1	−8·2	4	...	...	*f*
	8	5	50	54	A. C.	−0 44 92	0·00	+0·32	+2 7·2	0·0	−8·7	3	22 10 18·08	88 12 15·1	*g*

Notes.

The observations are corrected for refraction and parallax. In computing the latter log Δ has been taken from Dr. Backlund's ephemeris in *Ast. Nach.* 3263, the values used being 9·9315, 9·9238, 9·9208, 9·9110, 9·8905 on December 27, 30, 31, January 3 and 8, respectively. The apparent errors of this ephemeris in R.A. and N.P.D. (tabular−observed) are +0ˢ·78, −17″·5 from star *a*; +0ˢ·28, −13″·6 from star *b*; −0ˢ·84, −11″·1 from star *c*; −1ˢ·13, +10″·6 from star *e*; −2ˢ·10, −2″·4 from star *g*. The observations are also corrected for the error of inclination of the wires, and, where necessary, for the motion of the comet.

December 30.—Sky hazy; clouds passing. Comet bright and distinct, with stellar condensation.

January 3.—The comet was faint, owing to bright moonlight.

The initials H., A. C., B., are those of Mr. Hollis, Mr. Crommelin, and Mr. Bryant, respectively.

Comparison Stars.

	Star's Name.		R.A.		N.P.D.		Authority.
			h m s		° ′ ″		
a	W.B. XXII., 239	1894·0	22 14 14·36	1894·0	86 16 27·6		Albany, Ast. Gesell. Catalogue, Munich, Schjellerup, and Göttingen Catalogues.
b	W.B. XXII., 227		22 13 29·56		86 23 12·9		Albany, Ast. Gesell. Catalogue, Munich and Göttingen Catalogues.
c	B.D. + 2°, 4497		22 15 39·58		86 50 57·2		Albany, Ast. Gesell. Catalogue.
d	B.D. + 2°, 4490		22 13 16·3		86 52·5		Bonn Observations, vol. iii.
e	W.B. XXII., 170	1895·0	22 10 46·27	1895·0	87 16 37·7		Albany, Ast. Gesell. Catalogue and Glasgow Catalogue, 1870.
f	B.D. + 2°, 4491		22 13 34·6		87 12·9		Bonn Observations, vol. iii.
g	B.D. + 1°, 4598		22 11 3·46		88 10 11·7		Munich Catalogue, 1880.

Royal Observatory, Greenwich: 1895 *January* 8.

Observations of Comets Sawerthal, 1888; *Davidson*, 1889; *Wolf*, 1891; *Holmes*, 1892; *Rordame-Quénisset*, 1893; *and Encke*, 1894, *made at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.*)

The following comet observations were made with the 10-inch Barclay Equatorial, using the ring-micrometer, with power 100.

Date.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log $(q \times \Delta)$.	Ref.
				Comet Sawerthal, 1888.									
1888.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
July 3	11 25 22	18 9 57	W.	−0 15·99	−2 48·6	4	1 3 3·58	0·25	9·7295	41 29 56·8	2·6	0·7415	(*a*)
5	11 7 27	17 59 53	F. B.	−3 50·00	−5 34·4	5	1 4 9·22	0·25	9·7276	41 4 25 6	2·7	0·7542	(*b*)
12	11 3 1	18 23 2	R.	+0 15·10	+5 37·5	12	1 7 5·05	0·26	9·7495	39 39 5·6	2·4	0·7169	(*c*)
Aug. 8	12 3 52	21 10 30	W.	−1 2·63	−1 1·6	12	0 59 49·44	0·24	9·7225	35 36 50·6	0·7	0·2077	(*d*)
				Comet Davidson, 1889.									
1889.													
Aug. 6	9 34 48	18 32 11	W.	−3 19·99	−7 24·9	3	14 52 7·59	0·63	9·4767	86 32 5·5	14·0	0·8262	(*e*)
6	9 36 33	18 33 56	W.	+1 11·71	−5 52·9	7	14 52 7·89	0·63	9·4790	86 31 58 3	14·0	0·8264	(*f*)
22	10 26 32	20 27 8	W.	+0 5·08	−0 4·8	12	15 54 1·52	0·48	9·5599	69 7 57·4	7·5	0·7582	(*g*)
Sept. 6	9 48 1	20 47 39	W.	−0 7·81	+1 27·0	9	16 29 31·01	0·36	9·5699	62 33 47·4	4·8	0·7027	(*h*)
				Comet Wolf, 1891.									
1891.													
Sept. 10	15 19 37	2 34 2	R.	+3 4·08	−5 51·6	4	3 53 31·48	0·14	9·1275	67 44 10·6	4·5	0·6473	(*i*)
10	15 35 41	2 50 8	R.	−1 38·00	+1 1·0	3	3 53 33·11	0·11	9·0323	67 44 25·3	4·5	0·6427	(*j*)
11	12 20 9	23 38 1	W.	+0 4·86	+4 54·1	6	3 55 16·44	0·37	9·5500	68 1 40·	5·7	0·7416	(*k*)
Oct. 28	10 40 20	1 3 13	R.	−8 17·88	+0 42·4	3	4 41 33·06	0·37	9·4736	90 32 10·5	8·7	0·8410	(*l*)
Nov. 25	10 18 16	2 31 29	R.	−1 8·93	+6 4·7	8	4 28 14·91	0·21	9·2603	102 2 35·7	8·7	0·8893	(*m*)
25	10 58 0	3 11 20	R.	−0 41·56	−8 24·4	5	4 28 14·20	0·14	9·0893	102 2 55·6	8 8	0·8939	(*n*)
1892.													
Jan. 6	9 25 4	4 31 45	R.	+1 7·93	+4 31·2	8	4 15 15·66	0·02	8·4283	103 39 58·2	6·2	0·9031	(*o*)
6	10 41 9	5 40 1	R.	+2 50·34	−5 9·1	8	4 15 16·02	0·11	9·1329	103 39 38·0	6·2	0 8985	(*p*)

Comet Holmes, 1892.

Date.	G.M.T.	Local Sidereal Time.	Obse. ver.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log $(q \times \Delta)$.	Ref.
1893.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Jan. 20	8 53 26	4 50 12	W.	−0 4·87	+1 56·4	6	1 27 2·17	0·14	9·5313	56 20 54·1	1·6	0·5831	(*q*)

Comet Rordame-Quénisset, 1893.

1893.													
July 10	10 14 19	17 25 29	W.	+3 32·62	−0 26·7	3	8 26 43·38	0·91	9·5814	42 53 4·2	18·0	0·8763	(*r*)
17	10 34 12	18 13 1	W.	−3 8·48	+0 44·0	6	10 55 40·50	0·69	9·6088	57 59 53·6	11·7	0·8335	(*s*)

Comet Encke, 1894.

1895.													
Jan. 8	6 39 28	1 46 40	R.	−3 3·36	−1 24·6	6	22 10 16·97	0·38	9·4712	88 12 44·3	8·8	0·8326	(*t*)

Observers' Remarks.

(*a*) Clouds keep passing. The tail can be traced across the diameter of the ring, but nucleus glimmers out now and then; the end of nebulosity observed. (*b*) Cloudy, but nucleus showed up brightly at times.

(*c*) Very difficult observation; so faint; barely visible at times. The nucleus only seen occasionally.

(*d*) The night exceptionally fine. The comet appeared as the faintest luminous haze; every now and then a coma showed itself as a brightening near the head of the luminosity.

(*e*), (*f*) The nucleus of comet is stellar, but rather dull, of the 9 mag., and surrounded by a coma; strong moonlight prevented a proper estimation of its width; wind gusty and sky hazy. (*g*) Coma encircling a nucleus of 10½ mag.

(*h*) A small, faint patch; stellar nucleus glimpsed at times. Difficult.

(*i*), (*j*) The nucleus, mag. 12, is just within the coma on the following side.

(*k*) Nucleus surrounded by nebulosity. Thin clouds came up. Observations made with great difficulty. (*l*) Nucleus is 12 mag.

(*m*), (*n*) Nucleus 13 mag. Cloudy at times. (*o*), (*p*) Comet exceedingly faint; moonlight.

(*q*) Thin clouds at times. At the commencement of the observations a star of the 11 mag. (the same estimated brightness as the nucleus) preceded so closely that the nucleus appeared to be double. There was no tail, but a fan-shaped coma.

(*r*) Coma is 2′ diameter, and a faint tail seems to proceed north. (On July 16 the comet easily visible to naked eye. Mag. 4.)

(*s*) Cloudy at end. (*t*) Comet faint; moonlight.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F. B., Mr. F. A. Bellamy.

Assumed Places of Comparison Stars.

Ref.	Mean R.A.	Reduction to Apparent R.A.	Mean N.P.D.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	1 3 18·57	+1·00	41 32 34·2	+11·2	Mean of Radcliffe, 1845. 347; Oeltz. Arg. (N.), 1155; Lalande, 2011.
(*b*)	1 7 58·17	+1·05	41 9 48·9	+11·1	Mean of Radcliffe, 1845, 379, and Paris, 1566.
(*c*)	1 6 48·57	+1·38	39 33 17·7	+10·4	Cambridge (Harvard), A. G., 559.
(*d*)	1 0 49·18	+2·89	35 37 46·1	+ 6·2	Mean of Radcliffe, 1845, 329, and Greenwich, 1872, 103, adopting proper motions of +0ˢ·386 in R.A., and +1″·56 in N.P.D.
(*e*)	14 55 26 68	+0·90	86 39 34·1	− 3·7	Albany, A. G., 5111.
(*f*)	14 50 55·31	+0·87	86 37 54·9	− 3·7	Albany, A. G., 5096.
(*g*)	15 53 55·59	+0·85	69 8 13·2	−11·0	Berlin, A. G., Zone 258.
(*h*)	16 29 38·11	+0·71	62 32 34 1	−13·7	Comparisons with W.B. (2) XVI., 985, and W.B. (2) XVI., 998–9.
(*i*)	3 50 25·58	+1·83	67 50 11·6	− 9·4	Radcliffe, 1890, 922.
(*j*)	3 55 9·30	+1·81	67 43 33·6	− 9·3	Radcliffe, 1890, 942.
(*k*)	3 55 9·75	+1·83	67 56 55·1	− 9·4	Comparisons with Radcliffe, 1890, 945.
(*l*)	4 49 48·29	+2·65	90 31 43·0	−14·8	Mean of Paris, 5643, and Göttingen, 1875, 1380–1.
(*m*)	4 29 20·75	+3·09	101 56 43 9	−12·9	Radcliffe, 1890, 1091.
(*n*)	4 28 52·68	+3·08	102 11 32·8	−12·8	Radcliffe, 1890, 1086.
(*o*)	4 14 7·32	+0·41	103 35 24·0	+ 3·0	Radcliffe, 1890, 1028.
(*p*)	4 12 25·27	+0·41	103 44 44·0	+ 3·1	Radcliffe, 1890, 1021.
(*q*)	1 27 7·91	−0·87	56 19 6 0	− 8·3	Radcliffe transit-circle observations, 1894 November 5, December 27.
(*r*)	8 23 10 60	+0·16	42 53 39·1	− 8·2	Paris, 10406.
(*s*)	10 58 48·25	+0·73	57 59 14·7	− 5·1	Leiden, A. G., Zones 170, 284.
(*t*)	22 13 21·08	−0·75	88 14 4·1	+ 4·8	Seeliger's Lamont, 30666.

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distances, Δ, are taken, except in the last case, from the *Astronomische Nachrichten*, as follows:—(*a*), (*b*), (*c*), No. 2838; (*d*), 2846; (*e*), (*f*), 2913 (*g*), (*h*), 2916; (*i*), (*j*), 3045; (*k*), (*l*), 3054; (*m*), (*n*), (*o*), (*p*), 3064; (*q*), 3140; (*r*), (*s*), 3173; (*t*), *Bulletin de l'Académie Impériale des Sciences de St. Pétersbourg*, 1894 Novembre.

Radcliffe Observatory, Oxford: 1895 *January* 10.

Estimations of Magnitude of Nova Aurigæ, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.

Estimations of the magnitude of the *Nova* have been made on the following twenty-three nights :—1893, January 16, 17, 20 ; February 4, 7, 8, 11, 16, 28 ; March 4, 10, 16, 27 ; April 4, 12, 21 ; May 3, 10 ; August 24 ; November 9. 1894, January 12, 23 ; and November 5. No sensible change was detected, the magnitude remaining at 9·7 on the scale published in the *Monthly Notices*, vol. lii. 6, p. 431, where a chart is given of the selected comparison stars.

Ephemerides of the Five Inner Satellites of Saturn, 1895.
By A. Marth.

Greenwich Noon. 1895.		P	L	B	*B*	A−L	Long. of Centr. Mer.	B′
		°	°	°	°	°	°	°
Feb.	25	359·953	215·661	+18·392	+16 808	−5·042	200·66	+20·28
Mar.	2	·940	215·555	18·337	16·865	4·782	105·10	20·22
	7	·922	215·410	18·270	16·921	4·481	9 57	20·14
	12	·899	215 226	18·191	16·977	4·141	274·06	20·06
	17	·872	215 005	18·102	17·033	3·765	178·55	19·96
	22	·840	214·751	18 003	17·090	3·356	83 05	19·85
	27	359·805	214·467	+17·896	+17·147	−2·917	347·55	+19·74
Apr.	1	·767	214·157	17·781	17·204	2·451	252·04	19·61
	6	·727	213 824	17·659	17·260	1·963	156·52	19·48
	11	·684	213·474	17·533	17·316	1·458	60·98	19·34
	16	·639	213·111	17·405	17·372	0·940	325·42	19·20
	21	·594	212·740	17·275	17·428	−0·413	229·83	19·06
	26	359·548	212 366	+17·146	+17·484	+0·116	134·21	+18 92
May	1	·503	211·994	17·019	17·539	0·644	38·55	18·78
	6	·458	211·628	16·895	17·594	1·165	302·84	18·65
	11	·415	211·274	16·777	17·650	1 675	207·09	18·52
	16	·374	210·935	16·666	17·705	2·170	111·29	18·40
	21	·335	210·616	16·563	17·760	2·645	15·43	18·29
	26	359·299	210·320	+16·471	+17·814	+3·097	279·52	+18·19
	31	·266	210·051	16·390	17·869	3·521	183·55	18·10
June	5	·237	209·813	16·321	17·924	3·9·5	87·53	18 02
	10	·212	209·607	16·235	17·978	4·277	351·45	17·96
	15	·191	209·436	16·223	18 032	4·604	255·30	17·92
	20	·175	209·301	16·195	18·086	4·895	159·10	17·89
	25	359·163	209·205	+16·182	+18·140	+5·148	62·85	+17·87
	30	·156	209·148	16·184	18 194	5·361	326·54	17·87
July	5	·154	209·130	16·201	18·248	5·535	230·17	17·89
	10	·157	299 152	16·233	18·302	5·669	133·76	17·93
	15	·164	209·214	16·280	18·355	5·764	37 30	17·98
	20	·176	209·315	16·342	18·408	5·820	300·80	18·05
	25	359·193	209·455	+16·417	+18·461	+5·837	204·26	+18·13

P denotes the position-angle of the axis of *Saturn*; $L+180°$ the planetocentric longitude of the Earth referred to the planet's equator; $\Lambda+180°$ that of the Sun, or $\Lambda-L$ the difference between the two. B and *B* denote the planetocentric latitudes of the Earth and Sun above the planet's equator, the inclination I and node N of which referred to the plane of the Earth's equator are assumed to be for

$$1895{\cdot}0 \quad I = 6°{\cdot}9391 \quad N = 126°{\cdot}0552.$$

The longitudes of *Saturn's* central meridian are a continuation of those given in the ephemerides for 1893 and 1894, the adopted daily rate of rotation being 844°·80. The differences between successive values, for an interval of five days, vary between 4223°·46 and 4224°·50.

The first column in the next table contains *Saturn's* brightness expressed in star-magnitudes according to the formula given by Professor G. Müller in his *Helligkeitsbestimmungen der Planeten*, in vol. viii. p. 366 of the Potsdam publications.

In the uncertainty of the real dimensions of *Saturn's* disc, I have for the present ephemeris adopted 17″·50 and 15″·75 as the values of the diameters at the distance 9·5389 and 40″·20 as that of the ring, though H. Struve's observations of conjunctions of satellites with the ends of the ring give 39″·2 (*v. Monthly Notices*, vol. liv. p. 470) or a value even smaller than Bessel's.

If $e=\sin\epsilon_0$ is the eccentricity of the planet's spheroid, or $\cos\epsilon_0$ the proportion of the polar to the equatorial diameter, the proportion of the apparent semi-axes *b* and *a* of the disc as seen from a distant point in planetocentric latitude B will be

$$\cos\epsilon = \cos\epsilon_0 \,.\, \sqrt{1+\tan^2\epsilon_0 \sin^2 B},$$

or

$$b = a\cos\epsilon = a\cos\epsilon_0 \,.\, \sec\nu,$$

if

$$\tan\nu = \tan\epsilon_0 \sin B.$$

If *y* is the distance of a belt from the centre of the disc measured along the polar semi-axis *b*, the latitude β' of the belt is found by

$$\sin(\beta'-B') = \frac{y}{b},$$

from which the planetocentric latitude β, if it should be required, may be deduced by

$$\tan\beta = \tan\beta' \,.\, \cos\epsilon_0.$$

The values of B′ found from

$$B'\tan B' = \tan B \sec\epsilon_0$$

are given in the last column of the preceding table.—In the tables for the five satellites, *a* and *b* denote the semi-axes of the

apparent orbits, l—L the orbital longitudes reckoned from the points which are in superior conjunction with the planet's centre or in opposition to the Earth in longitude. By adding to l—L the value of L from the preceding table, the longitudes l are found, which are already corrected for the equation of light.

Greenwich Noon.	b's Mag.	Semidiameter of Ball. Equat.	Defect.	Polar.	Semiaxis of Ring. Major	Minor.	*Mimas.* a_1	b_1	l_1—L
1895	m	″	″	″	″	″	″	″	°
Feb. 25	0·63	9·01	0·035	8·21	20·71	6·53	27·68	+8·73	151·64
Mar. 2	0·61	9·08	·032	8·27	20·87	6·56	27·89	8·78	261·93
7	0·58	9·15	·028	8·33	21·02	6·59	28·10	8·81	12·25
12	0·55	9·21	·024	8·39	21·16	6·61	28·29	8·83	122·59
17	0·53	9·27	·020	8·44	21·29	6·62	28·46	8·84	232·96
22	0·50	9·32	·016	8·48	21·41	6·62	28·62	8·85	343·35
27	0·47	9·37	·012	8·52	21·52	6·61	28·76	+8·84	93·75
Apr. 1	0·45	9·41	·009	8·56	21·61	6·60	28·88	8·82	204·16
6	0·42	9·44	·006	8·59	21·68	6·58	28·98	8·79	314·58
11	0·40	9·46	·003	8·61	21·74	6·55	29·06	8·75	65·01
16	0·38	9·48	·001	8·62	21·78	6·51	29·11	8·71	175·43
21	0·36	9·49	·000	8·63	21·80	6·47	29·14	8·65	285·84
26	0·35	9·49	...	8·63	21·80	6·43	29·14	+8·59	36·24
May 1	0·37	9·48	·000	8·62	21·79	6·38	29·12	8·52	146·62
6	0·41	9·47	·002	8·60	21·75	6·32	29·07	8·45	256·97
11	0·44	9·44	·004	8·58	21·69	6·26	29·00	8·37	7·30
16	0·47	9·41	·007	8·55	21·62	6·20	28·90	8·29	117·60
21	0·51	9·37	·010	8·52	21·54	6·14	28·79	8·21	227·86
26	0·54	9·33	·014	8·48	21·44	6·08	28·65	+8·12	338·09
31	0·57	9·28	·018	8·43	21·32	6·02	28·50	8·04	88·28
June 5	0·60	9·22	·022	8·38	21·19	5·96	28·33	7·96	198·42
10	0·64	9·16	·026	8·32	21·05	5·90	28·14	7·88	308·52
15	0·67	9·10	·029	8·26	20·90	5·84	27·94	7·81	58·57
20	0·70	9·03	·033	8·20	20·75	5·79	27·74	7·74	168·58
25	0·72	8·96	·036	8·14	20·59	5·74	27·52	+7·67	278·54
30	0·75	8·89	·038	8·08	20·42	5·69	27·30	7·61	28·45
July 5	0·78	8·82	·040	8·01	20·25	5·65	27·07	7·55	138·32
10	0·80	8·74	·042	7·94	20·08	5·61	26·85	7·50	248·15
15	0·82	8·67	·044	7·87	19·91	5·58	26·62	7·46	357·93
20	0·84	8·60	·044	7·81	19·74	5·56	26·39	7·43	107·67
25	0·86	8·52	0·044	7·74	19·58	5·53	26·17	+7·40	217·37

The differences of successive values of l_1 − L vary between 1909°·70 and 1910°·43.

	Enceladus.				*Tethys.*			
	a_2-	b_2	l_2-L	Diff.	a_3	b_2	l_2-L	Diff.
1895.	″	″	°	°	″	″	°	°
Feb. 25	35·51	+11·20	44·06	1313 87	43·96	+13·87	278·28	953 67
Mar. 2	35·78	11·26	277·93	·91	44·30	13·94	151·95	·71
7	36·04	11·30	151·84	·94	44·62	13·99	25·66	·73
12	36·29	11·33	25·78	·96	44·92	14·02	259·39	·77
17	36·51	11·35	259·74	1313·99	45·20	14·04	133·16	·80
22	36·72	11·35	133·73	1314·01	45·45	14·05	6·96	·82
27	36·90	+11·34	7·74	·03	45·68	+14·04	240 78	·84
Apr. 1	37·05	11·32	241·77	·04	45 87	14·01	114·62	·85
6	37·18	11·28	115 81	·04	46·03	13·96	348·47	·86
11	37·28	11·23	349·85	·05	46·15	13·90	222·33	·87
16	37·35	11·17	223·90	·04	46·23	13·83	96·20	·87
21	37·38	11·10	97 94	·04	46·27	13·74	330·07	·86
26	37·38	+11·02	331·98	·02	46·28	+13 64	203·93	953·85
May 1	37·35	10·93	206·00	1314·00	46·24	13·53	77·78	·84
6	37·29	10·84	80·00	1313·98	46·17	13·42	311·62	·82
11	37·20	10·74	313·98	·96	46·05	13·29	185·44	·79
16	37·08	10·63	187·94	·92	45·90	13·16	59·23	·77
21	36·93	10·53	61·86	·89	45·72	13·03	293·00	·73
26	36·76	+10·42	295·75	·85	45·50	+12·90	166·73	·70
31	36·56	10·32	169·60	·82	45·25	12·77	40·43	·67
June 5	36·34	10·21	43·42	·78	44·98	12·64	274 10	·63
10	36·10	10·11	277·20	·73	44·69	12·52	147·73	·59
15	35·85	10·01	150·93	·69	44·38	12·40	21·32	·55
20	35·58	9·92	24·62	·65	44·05	12·29	254·87	·50
25	35·30	+ 9·84	258·27	·60	43·70	+12·18	128·37	·46
30	35·02	9·76	131·87	·56	43·35	12·08	1·83	·42
July 5	34·73	9·69	5·43	·52	42·99	12·00	235·25	·38
10	34·44	9·63	238·95	·47	42 63	11·92	108·63	·33
15	34·15	9·57	112·42	·43	42·27	11·85	341·96	·29
20	33·86	9·53	345·85	1313·40	41·91	11·79	215·25	953·26
25	33·57	+ 9·49	219·25		41·56	+11·75	88·51	

		Dione.				*Rhea.*			
1895.		a_4	b_4	$l_4-L.$	Diff.	a_5	b_5	$l_5-L.$	Diff.
		″	″	°	°	″	″	°	°
Feb.	25	56·30	+17·76	73·19	657·83	78·63	+24·81	311·17	398·59
Mar.	2	56·73	17·85	11·02	·87	79·23	24·93	349·76	·63
	7	57·14	17·91	308·89	·91	79·80	25·02	28·39	·66
	12	57·53	17·96	246·80	·94	80·34	25·08	67·05	·70
	17	57·89	17·99	184·74	·96	80·84	25·12	105·75	·73
	22	58·21	17·99	122·70	657·99	81·30	25·13	144·48	·75
	27	58·50	+17·98	60·69	658·02	81·70	+25·10	183·23	·78
Apr.	1	58·75	17·94	358·71	·03	82·04	25·05	222·01	·79
	6	58·95	17·88	296·74	·04	82·32	24·97	260·80	·81
	11	59·11	17·81	234·78	·05	82·54	24·87	299·61	·82
	16	59·21	17·71	172·83	·05	82·69	24·74	338·43	·83
	21	59·27	17·60	110·88	·05	82·77	24·58	17·26	·82
	26	59·27	+17·47	48·93	·04	82·77	+24·40	56·08	·82
May	1	59·22	17·33	346·97	·03	82·71	24·21	94·90	·81
	6	59·13	17·18	285·00	658·02	82 57	24·00	133·71	·80
	11	58·98	17·02	223·02	657·99	82·37	23·78	172·51	·77
	16	58·79	16·86	161·01	·96	82·10	23·55	211·28	·75
	21	58·55	16·69	92·97	·94	81·77	23·31	250·03	·73
	26	58·27	+16·52	36·91	·91	81·38	+23·07	288·76	·70
	31	57·96	16·35	334·82	·87	80·94	22·84	327·46	·66
June	5	57·61	16·19	272·69	·83	80·46	22·61	6·12	·63
	10	57·24	16·03	210·52	·80	79 93	22·39	44 75	·59
	15	56·84	15·88	148·32	·76	79·37	22·17	83·34	·56
	20	56·41	15·73	86·08	·72	78·78	21·97	121·90	·51
	25	55·97	+15·60	23 80	·67	78·17	+21·78	160·41	·47
	30	55·52	15·48	321·47	·63	77·54	21 61	198·88	·44
July	5	55·06	15·36	259·10	·60	76·90	21·46	237·32	·39
	10	54·60	15·26	196·70	·55	76·25	21·32	275·71	·35
	15	54·14	15·18	134·25	·51	75·61	21·20	314·06	·31
	20	53·68	15·10	71·76	657·47	74·96	21·09	352·37	398·27
	25	53·22	+15·04	9·23		74·33	+21·01	30·64	

These values are to be interpolated for the times for which the apparent places of the satellites are required, when the position-angles p and distances s, or the rectangular coordinates x and y referred to the axes of the disc of *Saturn*, are found by means of the formulæ

$$s \sin (p-\mathrm{P}) = x = a \sin (l-\mathrm{L})$$
$$s \cos (p-\mathrm{P}) = y = b \cos (l-\mathrm{L}).$$

Approximate Greenwich times of conjunctions of the satellites with the centre of the planet, or of their crossing the direction of the polar axis of the ball; "*n*" satellite north, in superior conjunction, moving from the preceding to the following side; "*s*" satellite south, in inferior conjunction, moving from the following to the preceding side. In the case of Rhea the times of the greatest elongations, "*e*" east, "*w*" west, are also given.

G.M.T. 1895.	h		G.M.T. 1895.	h		G.M.T. 1895.	h	
Feb. 25	10·3	Te. *n*	Mar. 6	0·5	Di. *s*	Mar. 15	14·3	Di. *n*
	12·2	En. *s*		10·1	En. *n*		16·2	Rh. *n*
	13·1	Mi. *n*		11·9	Mi. *s*		22·1	Mi. *s*
	14·7	Rh. *n*		15·4	Rh. *n*	16	0·3	En. *n*
	19·5	Di. *s*		20·8	Te. *n*		7·2	Te. *n*
26	0·4	Mi. *s*		23·2	Mi. *n*		9·4	Mi. *n*
	8·9	Te. *s*	7	9·3	Di. *n*		16·7	En. *s*
	11·7	Mi. *n*		10·5	Mi. *s*		19·3	Rh. *e*
	17·8	Rh. *e*		18·5	Rh. *e*		20·7	Mi. *s*
	21·3	En. *s*		19·0	En. *n*		23·1	Di. *s*
	23·0	Mi. *s*		19·4	Te. *s*	17	5·9	Te. *s*
27	7·6	Te. *n*		21·8	Mi. *n*		8·0	Mi. *n*
	10·3	Mi. *n*	8	11·4	En. *s*		9·2	En. *n*
	13·7	En. *n*		18·1	Te. *n*		19·3	Mi. *s*
	20·9	Rh. *s*		18·1	Di. *s*		22·3	Rh. *s*
	21·6	Mi. *s*		20·5	Mi. *n*	18	8·0	Di. *n*
28	13·2	Di. *s*		21·6	Rh. *s*		17·9	Mi. *s*
	20·2	Mi. *s*	9	16·7	Te. *s*		18·0	En. *n*
	22·6	En. *n*		19·1	Mi. *n*	19	10·5	En. *s*
Mar. 1	15·0	En. *s*		20·3	En. *s*		16·5	Mi. *s*
	18·8	Mi. *s*	10	0·7	Rh. *w*		16·8	Di. *s*
	22·0	Di. *n*		12·8	En. *n*	20	4·5	Rh. *n*
2	17·5	Mi. *s*		15·4	Te. *n*		15·1	Mi. *s*
	23·9	En. *s*		17·7	Mi. *n*		19·3	En. *s*
3	6·2	Rh. *e*	11	11·8	Di. *s*	21	0·5	Te. *s*
	6·8	Di. *s*		14·0	Te. *s*		7·6	Rh. *e*
	16·1	Mi. *s*		16·3	Mi. *n*		11·8	En. *n*
	16·4	En. *n*		21·6	En. *n*		15·7	Mi. *s*
4	0·8	Te. *s*	12	6·9	Rh. *e*		23·1	Te. *n*
	9·3	Rh. *s*		12·6	Te. *n*	22	10·4	Di. *s*
	14·7	Mi. *s*		14·1	En. *s*		10·7	Rh. *s*
	15·7	Di. *n*		14·9	Mi. *n*		12·3	Mi. *s*
	23·5	Te. *n*		20·6	Di. *s*		20·7	En. *n*
5	12·4	Rh. *w*	13	10·0	Rh. *s*		21·8	Te. *s*
	13·3	Mi. *s*		11·3	Te. *s*	23	11·0	Mi. *s*
	17·7	En. *s*	14	9·9	Te. *n*		13·1	En. *s*
	22·1	Te. *s*		13·1	Rh. *w*		13·8	Rh. *w*

G.M.T.			G.M.T.			G.M.T.		
1895.	h		1895.	h		1895.	h	
Mar. 23	19·3	Di. *n*	Apr. 6	22·3	En. *n*	Apr. 21	16·0	Mi. *s*
	20·4	Te. *n*	7	0·1	Te. *s*		21·9	Rh. *e*
	22·3	Mi. *n*		12·8	Mi. *s*	22	14·6	Mi. *s*
24	16·9	Rh. *n*		14·7	En. *s*		16·4	En. *s*
	19·1	Te. *s*		20·4	Di. *s*		21·4	Di. *n*
	20·9	Mi. *n*		22·7	Te. *n*	23	8·8	En. *n*
	22·0	En. *s*	8	8·9	Rh. *e*		13·2	Mi. *s*
25	14·4	En. *n*		11·4	Mi. *s*	24	6·2	Di. *s*
	17·7	Te. *n*		21·4	Te. *s*		11·8	Mi. *s*
	19·5	Mi. *n*	9	12·0	Rh. *s*		17·7	En. *n*
	19·9	Rh. *e*		20·0	Te. *n*	25	7·1	Rh. *n*
26	12·9	Di. *n*	10	14·0	Di. *s*		10·1	En. *s*
	16·3	Te. *s*		15·1	Rh. *w*		10·4	Mi. *s*
	18·1	Mi. *n*		18·7	Te. *s*		15·1	Di. *n*
	23·0	Rh. *s*	11	17·3	Te. *n*		21·0	Te. *s*
	23·3	En. *n*		17·4	En. *s*	26	9·0	Mi. *s*
27	15·0	Te. *n*		18·2	Rh. *n*		10·2	Rh. *e*
	15·7	En. *s*		18·5	Mi. *n*		19·0	En. *s*
	16·7	Mi. *n*		22·8	Di. *n*		19·6	Te. *n*
	21·8	Di. *s*	12	9·8	En. *n*		20·3	Mi. *n*
28	13·6	Te. *s*		16·0	Te. *s*	27	11·4	En. *n*
	15·3	Mi. *n*		17·1	Mi. *n*		13·3	Rh. *s*
29	5·2	Rh. *n*		21·2	Rh. *e*		18·3	Te. *s*
	6·6	Di. *n*	13	7·7	Di. *s*		18·9	Mi. *n*
	12·3	Te. *n*		14·6	Te. *n*	28	8·7	Di. *n*
	13·9	Mi. *n*		15·7	Mi. *n*		16·4	Rh. *w*
	17·0	En. *n*		18·7	En. *n*		16·9	Te. *n*
30	8·3	Rh. *e*	14	0·3	Rh. *s*		17·6	Mi. *n*
	9·5	En. *s*		11·1	En. *s*		20·3	En. *n*
	10·9	Te. *s*		13·2	Te. *s*	29	12·7	En. *s*
	12·6	Mi. *n*		14·4	Mi. *n*		15·6	Te. *s*
	15·4	Di. *s*		16·5	Di. *n*		16·2	Mi. *n*
31	9·6	Te. *n*	15	11·9	Te. *n*		17·6	Di. *s*
	11·2	Mi. *n*		13·0	Mi. *n*		19·4	Rh. *w*
	11·4	Rh. *s*		20·0	En. *s*	30	14·2	Te. *n*
	18·4	En. *s*	16	6·5	Rh. *n*		14·8	Mi. *n*
Apr. 1	8·2	Te. *s*		10·5	Te. *s*		21·6	En. *s*
	9·8	Mi. *n*		11·6	Mi. *n*		22·5	Rh. *e*
	10·8	En. *n*		12·4	En. *n*	May 1	12·9	Te. *s*
	14·4	Rh. *w*	17	9·2	Te. *n*		13·4	Mi. *n*
	21·1	Mi. *s*		9·6	Rh. *e*		14·1	En. *n*
2	6·9	Te. *n*		10·1	Di. *n*	2	11·2	Di. *s*
	8·4	Mi. *n*		10·2	Mi. *n*		11·5	Te. *n*
	9·1	Di. *s*		21·3	En. *n*		12·0	Mi. *n*
	17·5	Rh. *n*		21·5	Mi. *s*	3	10·1	Te. *s*
	19·7	En. *n*	18	7·8	Te. *s*		10·6	Mi. *n*
	19·7	Mi. *s*		8·8	Mi. *n*		15·4	En. *s*
3	12·1	En. *s*		12·6	Rh. *s*		20·0	Di. *n*
	17·9	Di. *n*		13·7	En. *s*	4	7·8	Rh. *n*
	18·3	Mi. *s*		19·0	Di. *s*		7·8	En. *n*
	20·6	Rh. *e*		20·1	Mi. *s*		8·8	Te. *n*
4	16·9	Mi. *s*	19	15·7	Rh. *w*		9·2	Mi. *n*
	21·0	En. *s*		18·7	Mi. *s*	5	7·4	Te. *s*
	23·7	Rh. *s*		22·6	En. *s*		7·9	Mi. *n*
5	13·4	En. *n*	20	15·1	En. *n*		10·8	Rh. *e*
	15·5	Mi. *s*		17·3	Mi. *s*		16·7	En. *n*
6	11·5	Di. *n*		18·8	Rh. *n*	6	9·1	En. *s*
	14·2	Mi. *s*	21	12·6	Di. *s*		13·7	Di. *n*

G.M.T. 1895.	h	
May 6	13·9	Rh. *s*
7	17·0	Rh. *w*
8	10·4	En. *n*
	15·0	Mi. *s*
	20·1	Rh. *n*
9	7·3	Di. *n*
	13·6	Mi. *s*
	19·3	En. *n*
10	11·8	En. *s*
	12·3	Mi. *s*
	16 2	Di. *s*
11	10·8	Mi. *s*
	20·6	En. *s*
	22·0	Te. ***n***
12	9·5	Mi. *s*
	13·1	En. *n*
	20·6	Te. *s*
	20·8	Mi. *n*
13	8·4	Rh. *n*
	9·8	Di. *s*
	19·3	Te. *n*
	19·4	Mi. *n*
14	11·5	Rh. *e*
	14·4	En. *s*
	17·9	Te. *s*
	18·0	Mi. *n*
	18·6	Di. *n*
15	14·6	Rh. *s*
	16·5	Te. *n*
	16·6	Mi. *n*
16	15·2	Te. *s*
	15·2	Mi. *n*
	15·7	En. *n*
	17·7	Rh. *w*
17	8·1	En. *s*
	12·3	Di. *n*
	13·8	Te. *n*
	13·8	Mi. *n*
	20·7	Rh. *n*
18	12·5	Mi. *n*
	12·5	Te. *s*
	17·0	En. *s*
	21·1	Di. *s*
19	9·5	En. *n*
	11·1	Mi. *n*
	11·1	Te. *n*
20	9 7	Mi. *n*
	9·8	Te. *s*
	18·3	En. *n*
21	8·4	Te. *n*
	10·8	En. *s*
	14·8	Di. *s*
	19·6	Mi. *s*
22	7·1	Te. *s*
	9·1	Rh. *n*
	18·2	Mi. *s*
	19·7	En. *s*

G.M.T. 1895.	h	
May 23	12·1	En. *n*
	12·2	Rh. *e*
	16·8	Mi. *s*
24	8·4	Di. *s*
	15·3	Rh. *s*
	15·4	Mi. *s*
25	13·4	En. *s*
	14·1	Mi. *s*
	17·3	Di. *n*
	18·4	Rh. *w*
26	12·7	Mi. *s*
	21·4	Rh. *n*
27	11·3	Mi. *s*
	14·7	En. *n*
28	9·9	Mi. *s*
	10·9	Di. *n*
29	16·1	En. *s*
	19·8	Di. *s*
	19·8	Mi. *n*
	20·3	Te. *s*
30	8·5	En. *n*
	18·4	Mi. *n*
	18·9	Te. *n*
31	9·8	Rh. *n*
	17·1	Mi. *n*
	17·4	En. *n*
	17·6	Te. *s*
June 1	9·8	En. *s*
	12·9	Rh. *e*
	13·4	Di. *s*
	15·7	Mi. *n*
	16·2	Te. *n*
2	14·3	Mi. *n*
	14·9	Te. *s*
	16·0	Rh. *s*
3	13·5	Te. *n*
	19·1	Rh. *w*
4	12·2	Te. *s*
5	10·1	Mi. *n*
	10·8	Te. *n*
	12·5	En. *s*
	15·9	Di. *n*
6	9·5	Te. *s*
7	8·1	Te. *n*
	13·8	En. *n*
	18·7	Mi. *s*
8	7·4	Rh. *w*
	9·6	Di. *n*
	17·3	Mi. *s*
9	10·5	Rh. *n*
	15·1	En. *s*
	15 9	Mi. *s*
	18·4	Di. *s*
10	13 6	Rh. *e*
	14·5	Mi. *s*
11	13·2	Mi. *s*
	16·4	En. *n*

G.M.T. 1895.	h	
June 11	16·7	Rh. *s*
12	8·9	En. *s*
	11·8	Mi. *s*
	12·1	Di. *s*
	19·8	Rh. *w*
13	10·4	Mi. *s*
	17·7	En. *s*
	20·9	Di. *n*
14	9·0	Mi. *s*
	10·2	En. *n*
	20·3	Mi. *n*
	21·3	Te. *n*
15	18·9	Mi. *n*
	19·1	En. *n*
	20 0	Te. *s*
16	11·5	En. *s*
	14·6	Di. *n*
	17·6	Mi. *n*
	18·6	Te. *n*
17	8·2	Rh. *w*
	16·2	Mi. *n*
	17·3	Te. *s*
18	11·3	Rh. *n*
	12·9	En. *n*
	14·8	Mi. *n*
	15·9	Te. *n*
19	8·3	Di. *n*
	13·4	Mi. *n*
	14·4	Rh. *e*
	14·6	Te. *s*
20	12·0	Mi. *n*
	13 2	Te. *n*
	14·2	En. *s*
	17·1	Di. *s*
	17·5	Rh. *s*
21	10·6	Mi. *n*
	11·9	Te. *s*
	20 6	Rh. *w*
22	Transit of Venus across Sun's disc (*v. M.N.* vol. liv. p. 173)	
	9·3	Mi. *n*
	10 5	Te. *n*
	15·5	En. *n*
23	9·2	Te. *s*
	10·8	Di. *s*
24	16·8	En. *s*
	17·8	Mi. *s*
25	9·3	En. *n*
	16 2	Mi. *s*
26	9·0	Rh. *w*
	15·0	Mi. *s*
	18·2	En. *n*
27	10·6	En. *s*
	12·1	Rh. *n*
	13·3	Di. *n*

G.M.T.			G.M.T.			G.M.T.		
1895.	h		1895.	h		1895.	h	
June 27	13·7	Mi. *s*	July 4	9·6	Di. *s*	July 7	13·0	Te. *n*
28	12·3	Mi. *s*		17·0	Te. *s*		16·1	Rh. *e*
	15·2	Rh. *e*	5	9·8	Rh. *w*	8	11·7	Te. *s*
29	10·9	Mi. *s*		15·7	Te. *n*		12·1	Di. *n*
	11·9	En. *n*		18·4	Di. *n*	9	10·3	Te. *n*
	18·3	Rh. *s*	6	13·0	Rh. *n*	10	9·0	Te. *s*
July 1	15·9	Di. *s*		14·4	Te. *s*			

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Erratum in *Monthly Notices*, vol. liv., No. 9, p. 262, of List of Presents, last paragraph but one from bottom, *for* J. M. Schaeberle *read* Lick Observatory.

Erratum in *Monthly Notices*, vol. liv., No. 9, p. 581: Comparison of Gale's Comet with stars *f* and *g* on 1894 June 28. In column of Greenwich Mean Solar Time *for* $28^{d}\ 11^{h}\ 19^{m}\ 3^{s}$ *read* $28^{d}\ 11^{h}\ 4^{m}\ 3^{s}$.